The Engineer

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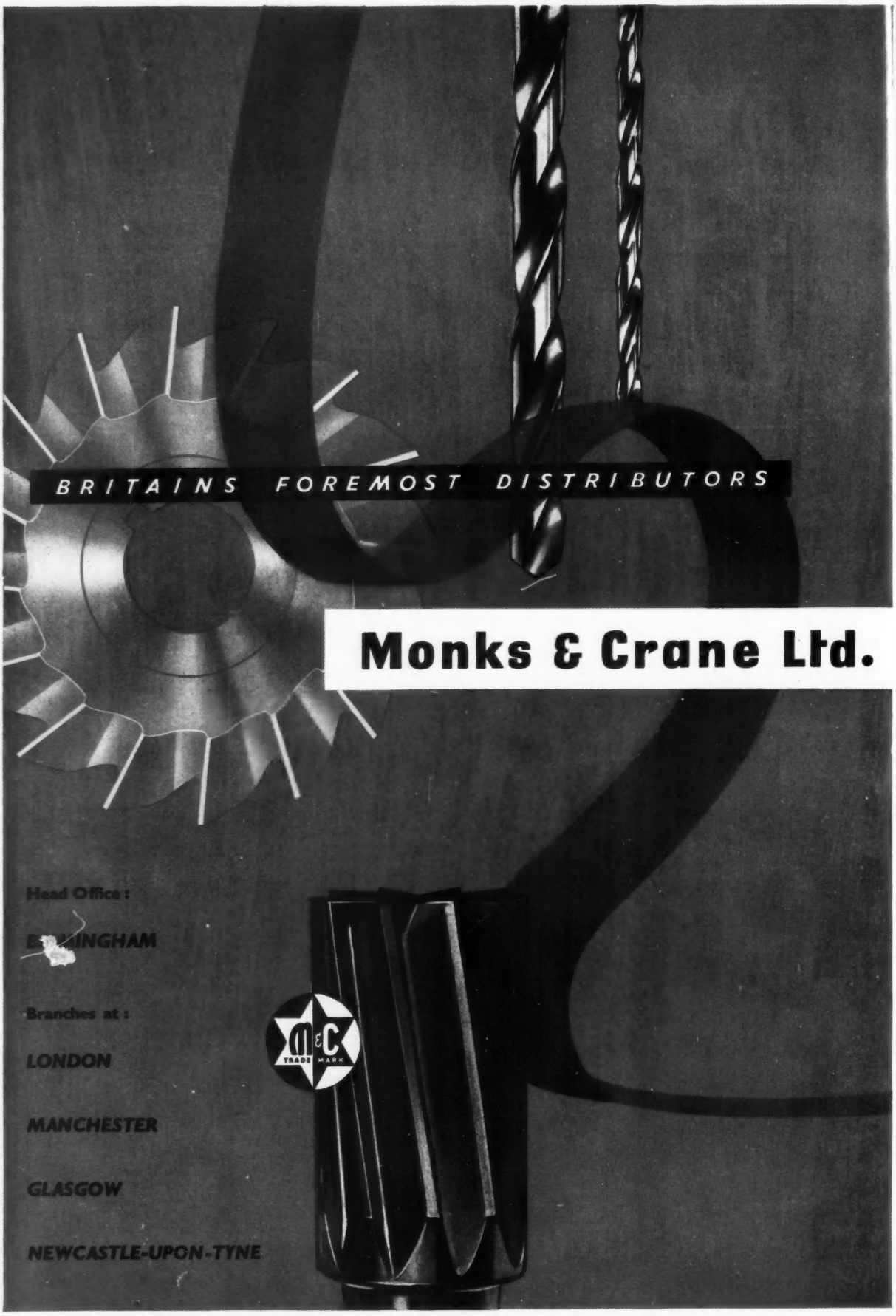
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NUCLEAR POWER DEVELOPMENT

In his lecture to the Institute of Physics on July 3rd, Sir John Cockcroft gave an excellent résumé of the scientific problems that will have to be solved in the development of nuclear power. Anyone not acquainted with this field of research and development, and who heard, or has read, this lecture must have been impressed by the variety, and complexity of these problems. They extend deeply into metallurgy and chemistry as well as into physics; and it is evident that, if the development of nuclear power is to proceed at a reasonable pace, many of these problems need to be tackled concurrently. In fact, it is essential that this happens, as it is frequently the information coming forward in one field of research that gives point and urgency to the work in another. There are even quite important gaps in fundamental data, and they can only be filled by results from difficult and expensive experiments. Sir John pointed out that in a programme of experiments to determine the nuclear constants of the fission products produced by the irradiation of a plutonium rod, the facilities required for isolating these fission products might well cost £50,000. Until, however, accurate information of this sort has been obtained much theoretical work can only give approximate answers. At present apparently, knowledge of nuclear constants is not certain enough to enable the burn-up that might be achieved with nuclear fuels to be predicted accurately. Yet the possible burn-up is an important factor in determining the length of time a fuel may remain in a reactor of given power before it must be removed for chemical processing to get rid of fission products. As this affects both the frequency of chemical processing and the fuel investment in the reactor and processing cycle, it has a direct bearing on calculations made to assess the future costs of nuclear power. Even supposing this data were available it might be found that the nuclear behaviour of the fuel was not the limiting factor on the length of time and rate at which it could operate in a reactor. In his lecture, Sir John mentioned how the effects of low-temperature irradiation of uranium cause it to distort badly. Fortunately, at the operating temperature of the Calder Hall type of reactor, it appears that this kind of distortion can be greatly reduced by suitable heat treatment of the fuel, and it therefore should not be a limit to burn-up. At higher temperatures, however, other problems are encountered due to the bulk swelling of the fuel because of the formation of fission gases.

No doubt the engineer will have been struck by the fact that the majority of the problems outlined affect not only the overall design of nuclear reactors, but the engineering details as well. A fuel element canning material for example must not only be a low absorber of neutrons, it must also be compatible with both the fuel and the coolant at the operating conditions of the reactor. But before the fuel container can be designed the engineer must know how the fuel is going to behave. He will also wish to know how the mechanical properties of the canning material alter under varying temperatures and under varying intensities of neutron and thermal fluxes. It is even possible that several materials need to be considered and alternative designs compared. This required data can, however, only be obtained by a comprehensive programme of experimental work. Similar difficulties exist in almost all spheres of design. Although useful pointers may have been obtained indicating that a certain material is likely to be a suitable fuel, or constructional material, or coolant, a very large amount of steady development work must be carried out before there is sufficient information available to make a reasonably sensible design possible.

Against this sort of background the choice of the gas-cooled graphite-moderated natural-uranium reactor as the Stage 1 reactor for the development of nuclear power in this country appears to be an eminently sensible decision. After the Geneva Conference on the Peaceful Uses of Atomic Energy last

August there was a tendency to look upon the large gas-cooled reactor of this kind as being already obsolete, and imaginations were caught by the advantages that are forecast for several of the other systems. It is apparent, however, that the majority of these systems still require a great deal of experimental work before the engineer can really get to grips with his design problems, and much data will have to be collected before real optimisation of design becomes possible. On the gas-cooled thermal reactor on the other hand, although much has still to be learnt about the behaviour of fuels and canning materials, for example, there is a wide field of opportunity for refinement and development of the engineering design which the engineer is able to work on now and which cannot help but reduce the costs of nuclear power from such a system. In fact it would appear that Great Britain has got away to a start on a type of reactor in which a large part of the design is reasonably independent of the development problems that are as yet unsolved. In May, the prototype gas-cooled reactor at Calder Hall became critical. Soon the Central Electricity Authority will be studying the proposed designs for its first nuclear power stations. Though these proposals will be based on the design of Calder Hall it will be interesting to see to what extent the design teams of the industrial firms concerned have already been able to improve on this prototype.

IMPORTANCE OF GOOD MANAGERS IN INDUSTRY

It was frequently remarked by the great Lord Bacon that " He knew himself to be fitter to hold a book than to play a part on the active stage of affairs " and in one of his essays he asserts that " The mind is the man. . . . A man is but what he knoweth." Indeed, Bacon, in his *New Atlantis* (written three and a half centuries ago), gives an exposition—far too little read in these days—of that " College of the Six Days Works," wherein the end aimed at was " the knowledge of causes and secret motions of things ; and the enlarging of the bounds of human empire to the effecting of all things possible " (*ad omne possibile*). Near the end of the *New Atlantis*, Bacon has something to say about management training in that place where he describes various categories of " employments and offices " and the services expected from groups such as the " merchants of light," the " depredators," the " mystery-men," the " pioneers or minders," the " dowry-men " or " benefactors," the " lamps," the " innoculators," and the " interpreters of nature." We should note that in the " College of the Six Days Works " much attention was paid to the discussion of the information and experience collected by the exploratory divisions. " We have also, as you must think, novices and apprentices, that the succession of the former employed men do not fail. . . . And this we do also : we have consultations, which of the inventions and experiences which we have discovered shall be published, and which not."

The above remarks are suggested by perusal of the address given by the chairman of Unilever, Ltd., at the annual general meeting of that company held on May 24th. This address can be described as a thesis on the importance of good managers in industry, and it merits the close attention of all those whose interests bring them into contact, directly or indirectly, with what is one of the most urgent and complex problems of the mid-twentieth century. Whatever may have been the degree of importance attached to this problem in Lord Bacon's time, it had become greatly intensified a century and a half later when Matthew Boulton, then the outstanding industrialist in Great Britain, found himself carrying the executive burden of a rapidly expanding manufacturing business which lacked the necessary inflow of skilled personnel. This was in and around the year 1770 and we find a letter dated October 1, 1770, in which, writing to James Adam, the architect, Boulton gives details not only of the manufacturing equipment at Soho but of the procedure followed in selecting draughtsmen from among the " young plain country lads " trained in the manufactory. Boulton also mentions the means employed in securing " such a number of hands as yields a choice of artists for the finer branches." In Boulton's case, the size of the manufacturing unit was, of course, very limited relatively to what is found in the bulk of our industry to-day, and that the problems of management are apt to increase with size is too well understood to require stressing. There is a limiting size to all industrial units and a prominent American manufacturer of precision equipment has recently remarked that " an industrial unit should never reach a size wherein a member cannot be assured of immediate and equitable revamping of undesirable working conditions and the redressing of any wrongs which may inadvertently be inflicted upon him." In the minds of those who guide the manufacturing industry of the United States there is, moreover, a rapidly growing recognition of the value of higher standards of education in the training of young executives whether they be intended for strictly technical work or for management. It is no use presuming that cultural influences can best be sought in later years. They must be acquired and brought into action at that early period of a man's life when what Lord Heyworth aptly calls " the germ of leadership " is most susceptible to cultivation. A powerful constituent of leadership is imagination and the imaginative faculties—like the intellectual faculties generally—are most active in early life.

Sir Isaac Newton has left it on record that in 1665 and 1666 (his twenty-third and twenty-fourth years) he was in the prime of his age for invention " and minded mathematics and philosophy more than at any time since." James Watt was thirty years of age when, walking in Glasgow Green one Sunday afternoon, he arrived at the idea of the separate condenser. Neither Watt nor Boulton received a university education, but, nourishing their conspicuous natural abilities by the reading of good authors and by conversation with their more highly educated contemporaries, they became cultured men themselves. To this culture they were much indebted since it was a constituent which strengthened their faculty for leadership. Lord Heyworth mentions that in the United States (the reference being to industries producing detergents, toilet preparations, foods and oils and fats), managers form 15 per cent of the total working force. The deduction drawn is that " the higher the degree of mechanisation and the more sophisticated the environment, the higher will be the ratio of managers required." If this pattern is likely to persist, great must be the inducement to cultivate in the managers those qualities which are most apt to raise the mental calibre of the managed. It is worth while remembering how, in *Utopia*, if any of the managers " prove not according to the expectation and hope of him conceived, he is forthwith plucked back to the company of artificers. And contrariwise, often it chanceth that a handicraftsman doth so earnestly bestow his vacant and spare hours in learning, and through diligence so profit therein, that he is taken from his handy occupation and promoted to the company of the learned." Not long since it was remarked by Dr. Vannevar Bush that " Education of the people is dependent on the means of communication that are available. In its simplest form, a teacher talking to a group of pupils, communication is an essential element. . . . To-day we have intricate and powerful means for the interchange of thought among the entire population. On the skill and wisdom with which these means are employed depend the stability and prosperity of our Republic." Contemplating the 16,400 junior managers referred to by the chairman of Unilever, Ltd., as having " to understand the art of handling, or ' managing ' other people," one cannot fail to be impressed by the paramount need for so training each individual in this army of managers that he shall become capable—as far as his capacity may allow—of inculcating wisdom as well as a trade and of promoting that fraternal spirit which is apt to be so potent in establishing and maintaining industrial harmony.

A Seven Day Journal

Railway Accident Reports

DURING the past week, the Ministry of Transport and Civil Aviation has published two reports, by Brigadier C. A. Langley, inspecting officer, of inquiries into railway accidents which occurred towards the end of last year. The first was the train derailment, on Sunday, November 20th, at Milton, near Didcot, in the Western Region of British Railways. The train involved was travelling from Treherbert to Paddington, and because of engineering works, had—like other up trains that day—to be diverted to the goods loop at Milton. The derailment was caused by the excessive speed of the train through the sharply curved crossover, and the casualties included eleven fatalities. The report says that, at the inquiry, the driver frankly admitted that he failed to see the distant and home signals at Milton and that he did not attempt to reduce speed until almost at the facing points, when his emergency brake application was much too late to be effective. Brigadier Langley remarks that the tests of the automatic train control equipment "proved its integrity beyond all doubt, but as it only functions at the distant signal, control of the brake application must be left in the driver's hands, and the chance of human error is always present." He adds that accidents caused by the disregard and subsequent unthinking cancellation of the A.T.C. warning and braking effect have been very rare indeed. The second report is concerned with the collision, on December 22nd, at Luton station in the London Midland region. A train from St. Pancras to Derby ran into the back of a St. Pancras–Leicester train which was standing in the station. The Derby train was travelling at about 20 m.p.h. About this collision, Brigadier Langley says that a serious error was made by the driver of the Derby train, who did not keep a proper look-out on approaching Luton. He failed to see the distant signal at caution, and when he did see the home signal at danger his brake application was too late to be effective. The report comments on the proximity of yellow lights around a factory adjacent to the line; although no complaints had been made about them previously steps were promptly taken to screen them to eliminate any possibility of confusion with the signal lights. Furthermore, the distant signal has been moved to a new site 310 yards to the rear of its old position. It now stands out very clearly, the report says, and the greater braking distance enables trains to travel in safety at higher speeds.

Proposed Route of Doncaster By-Pass

THE Minister of Transport and Civil Aviation, has published the proposed line of a £5,000,000 by-pass on the Great North Road, A.1, at Doncaster. The by-pass will be 15 miles long with twin carriageways each 24ft wide. Details of the draft scheme are available at offices of the Councils concerned in the West Riding of Yorkshire and Nottinghamshire. The northern end will be at a point on the Great North Road about a quarter of a mile north of the junction with the Doncaster-Wakefield Trunk Road, A.638, at Red House, and it will extend southward to join the Nottingham-Bawtry Trunk Road, A.614, about a mile north of the village of Blyth. Traffic will then use the East Retford By-Pass, A.614 and A.57, rejoining A.1 at Markham Moor. With the exception of a very short length of general purpose road at the northern end, the new by-pass will be constructed as a road for motor traffic only. It will pass under or over nineteen intersecting roads and, excluding the roundabout junctions at each end, access to it will be limited to three intermediate points, where vehicles will enter or leave the road on the nearside of the traffic stream. The gradients are undulating with a maximum of 1 in 30 in the northern part of the by-pass. In the vicinity of Sprotborough the new road will be carried over the River Don by a high level viaduct which will be about 70ft above river level and approximately 800ft in length. Altogether some twenty-six bridges will be required. They will include two bridges over and four bridges under railways. The scheme which will connect with the London Yorkshire Motorway, is among those which the Ministry proposes to start within the next three years.

The Engineer

100 Years Ago

(JULY 18, 1856)

"TRADE MORALITY"

"We wish we could, with all the force of simple truth, give utterance to the sentiment embodied in a very homely expression, that there are delinquencies and delinquents in every trade but our own . . . But there are members of our craft, we fear, whose conduct is as open to suspicion and as worthy of condemnation as any other. Poor human nature has a great deal to answer for! We are not going to theologise, or recite the Commandments. We have to deal with existing evils; others more severe than we are today may call it dishonesty; we are content to term it trade immorality.

"One sin of which we are guilty is the constant indifference we pay to the rights of patentees. It is a fact which it is of no use to disguise, for none but the wilfully blind and wickedly obstinate will deny it, that there is at this moment a greater disregard than ever to the sanctity of patent right. Of all existing patentees, we will venture to say that four-fifths are either engineers—or are in, or are immediately connected with, mechanical trades. The truth is, we are preying upon each other, eating each other up, now and then giving the lawyers a surfeit . . . We are not disposed to believe that systematic infringements are premeditated—studied. They are consequent upon a laxity of principle in reference to patent right which has been gradually growing amongst us, and which is supposed to be to some extent excusable, because of the vast number of patents taken out under the new law, with the nature of each of which it is utterly impossible for the individual to become acquainted . . . We should be pleased to see, and it would tell better for our trade morality were there a general disposition evidenced to acknowledge the rights of the patentee when an infringement is detected. If the alleged violation be unintentional, the duty of the user is at once to satisfy himself of the legality of the patentee's claim, and to pay any moderate royalty demanded."

Royal Naval Engineering College at Manadon

IN 1940, the Royal Naval Engineering College was opened at Manadon on the outskirts of Plymouth as the first step in the scheme to replace Keyham as the training ground for engineers for the Navy. Temporary accommodation buildings were erected and during the succeeding years addition. included a permanent instructional blocks Both establishments were commissioned as H.M.S. "Thunderer" in 1945 and six years later the second phase in the development of the college was completed when the engineering workshops were finished. Another important phase in the slow development of the scheme was the granting of approval to build the accommodation block, and on Friday, July 13th, the foundation stone of the new wardroom mess was laid. The ceremony was carried out by Admiral The Earl Mountbatten of Burma in the presence of the Commander-in-Chief, the Engineer-in-Chief of the Fleet, the Admiral Superintendent, Devonport, and other naval officers and also the Lord Mayor of Plymouth. A glass container enclosing a copy of the house journal of the College, coins, a daily newspaper and a list of officers at the college was placed inside a lead casket laid in a cavity under the stone. Before lowering the stone into position the First Sea Lord gave a short address, during the course of which he mentioned that his father had raised his flag in the last ship to bear the name "Thunderer" and that he, Earl Mountbatten, had spent a term at Keyham at the beginning of his sea career. After the address a religous service was held during which the actual stone laying ceremony took place. The new building, which is being constructed by Richard Costain, Ltd., was begun this year and is expected to be completed by 1958. It is of reinforced concrete, measuring about 400ft by 36ft, and will be four stories high and faced with Portland Stone with limestone rubble walling at the gable ends.

Department of Scientific and Industrial Research

THE Department of Scientific and Industrial Research Bill was given its third reading in the House of Commons last Monday evening. It provides for the establishment of a Research Council whose function will be to further the practical application of the results of scientific and industrial research. The Bill followed the reports of a committee, of which Sir Harry Jephcott was chairman, which was set up by the Lord President of the Council to inquire into the organisation and functioning of the D.S.I.R. During last Monday's debate Mr. J. R. Bevins, Parliamentary Secretary to the Ministry of Works, who spoke for the Government, said that several members had questioned whether the replacement of the existing advisory council by the new research council would make very much difference in actual practice. Precisely how much difference it would make was, of course, a matter which only experience would show. But, Mr. Bevins observed, he did not think an advisory body, however distinguished, was the same as a body which possessed executive powers. The new council would have the duty of deciding upon and not merely advising upon the priorities and the balance of the Department's research programme as a whole. It would decide whether there were any new research tasks which the D.S.I.R. ought to undertake and whether any of its existing work should be expanded or, perhaps, tempered down. One of the council's first duties, and indeed a continuing duty, Mr. Bevins said, would be to follow up the suggestion of the Jephcott committee that many of the D.S.I.R.'s programmes had become "too diffused or too uneven in their quality." But the practical methods by which items in the D.S.I.R. programme were pursued, Mr. Bevins explained, would remain the responsibility of the directors of the research stations.

Study of Underground Water Movements by Measurements in Drill Holes

By GORDON NEWSTEAD* and J. C. JAEGER†

This article describes an instrument which may be useful in engineering work for measuring small flows of water along or across drill holes at depths up to some hundreds of feet. It was developed in connection with experiments on the determination of thermal conductivity of rocks by measurements in drill holes. In these experiments a "probe," consisting of a heater about 5ft long and a temperature measuring device, is lowered down the hole and, in principle, the thermal conductivity of the rock through which the hole is drilled can be calculated from a graph of the temperature of the probe against the time after the heater is switched on. The great difficulty in such experiments is to prevent loss of heat from the probe by convection. In order to do this, the portion of the hole containing the heater must be fairly effectively sealed off from the rest of the hole. Various methods of doing this have been tried, among them the present pneumatic seal.

1. Introduction

THE first attempt to measure thermal conductivity in the field with this instrument was made on the hole discussed in section 4. This was full of water to the collar, but there was no flow of water out of the hole. When the probe was lowered to 50ft and the seals inflated it was found that water receded in the hole: this immediately suggested that water was flowing up the hole from greater depths and out through some fissure below the surface. It was found to be possible to locate and measure the flow with this apparatus.

There are many different ways in which this instrument might be useful in engineering practice, such as:

(i) In dam or tunnel work it is important to be able to locate and measure moderate flows of water through fissures.

(ii) In connection with heat pumps, refrigerated cofferdams and similar problems it is necessary to be able to measure slow movements of water through porous media.

These applications will be discussed in sections 3 and 5, respectively.

2. Description of Apparatus

The equipment, shown schematically in Fig. 1 (*a*), consists of a measuring head with pneumatic seals which is lowered down the borehole and which is connected by an air line hose, and also electrically, to apparatus at the top of the hole. The electrical connections are taken down the centre of the air line hose, which is reinforced to take the weight and so forms a single composite connection. Standard air line fittings are mainly used. The pneumatic device seals the hole at the ends of the measuring portion of the head by inflating the two "Ductube" seals by compressed air from the top of the hole. These inflatable seals are of the type commonly used for preforming holes in concrete work. The compressed air apparatus comprises the air cylinder, regulating valve, air pressure gauge and release valve as shown in the figure. An air pressure of approximately 100 lb per square inch plus the static head of water is used to seal the hole completely.

The measuring head is shown in Fig. 1 (*b*) and consists of a thermistor connected by a coaxial cable passing through the centre of the air line hose to a bridge at the top for measuring the temperature. This apparatus is the same as that previously described by Newstead and Beck.‡ There is also a 20 ohm heating element between the seals to which heat is supplied electrically by means of a 60V battery at the top of the hole, the connection to the heating element being by a flexible wire and the earth braid of the coaxial cable. The measuring head is made of two brass tubes screwed together at the centre and sealed with a Neoprene "O" ring seal. Each tube carries a winding of 40 ohms in a spiral groove of two turns per inch. These windings are connected together to the tube (which is also joined to the braid of the coaxial cable) at its centre and insulated from the tube elsewhere by fibre glass insulation and baked varnish. At each end of the tube the spiral passes over insulating bushes screwed into the tube and sealed with "O" rings. The two outside ends of the windings terminate on brass sections screwed on to the outside ends of the insulating bushes and are

* University of Tasmania.
† Australian National University.

‡ *Aust. J. Phys.*, Vol. 6 (1953), page 480.

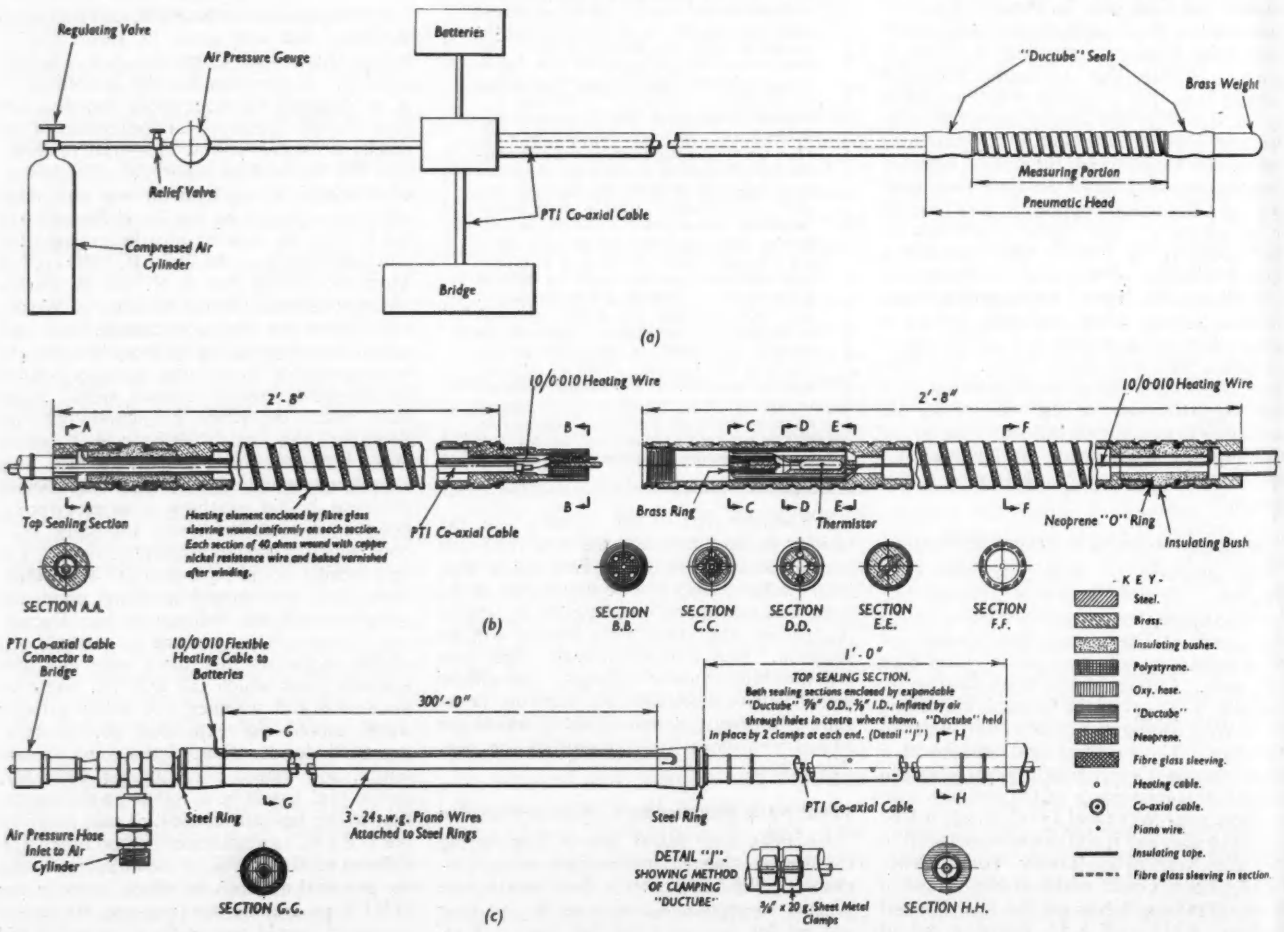


Fig.1

joined in parallel inside as shown. The flexible wire supplying the heater, together with three 20 S.W.G. steel piano wires, are fixed to the outside of the air line hose by coating it with "Neoprene" solution and binding with insulation tape. This wire is joined to the top outside brass section of the head. The piano wires serve to reinforce the air line hose mechanically so as to prevent it stretching. If the hose is to be wound on a small diameter reel two piano wires placed at the extremities of a diameter should be used so that the wires do not have to stretch to accommodate the small radius of curvature. The arrangement of the composite connection

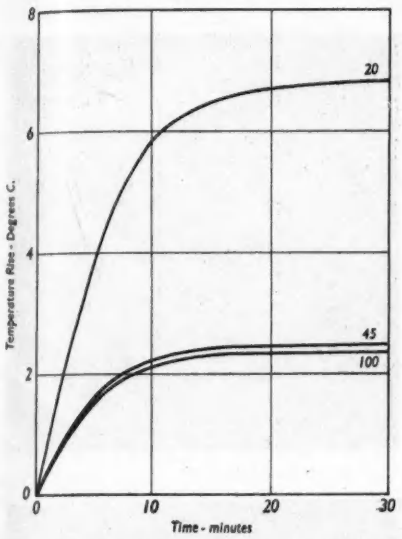


Fig. 2—Temperature-time measurements at 100ft, 45ft and 20ft depths

is shown in Fig. 1(*c*), which also shows the termination of the air line hose, cable and heating wire at the top of the hole. The bottom end of the measuring head, which carries the thermistor, is unscrewed for transport.

The apparatus was built for use in "EX" holes, 1⅝in in diameter, which are those commonly used in Tasmania in exploratory diamond drilling. For use in holes of other sizes it is simply necessary to unscrew the sealing sections carrying the "Ductube" and replace with others of the appropriate size.

The use of pneumatic seals offers little difficulty; 300ft of hose is used in the present equipment (this being about the maximum amount it is possible to man-handle), and this, together with a small gas cylinder and the electrical equipment, is easily transported in a Land Rover. It may be added that we have used a thermistor and an a.c. bridge for measuring temperature because this equipment was available; any other method would be equally suitable.

The equipment may be used in several different ways:

(*i*) If both seals are inflated it gives the thermal conductivity of the rock if there is no flow across the hole, or it measures the flow if one exists.

(*ii*) If both seals are partially inflated so that water can flow along the hole past the head, this flow can be measured (the partial inflation is intended to give as good mixing as possible of the flowing water).

(*iii*) It is possible to inflate one seal only by slipping a metal tube over the other seal, and in this way a flow into or out of a bore-hole may be located.

(*iv*) By inflating the seals, flow under a head of up to 150 lb per square inch may be stopped completely.

(3) Approximate Theory

The simplest possible idealisation of the apparatus, neglecting conduction of heat into the rock and assuming that the apparatus itself is a perfect conductor of heat, is that of a mass M of water (made up of the water between the seals and the water equivalent of the measuring head) to which heat is supplied by the heater at the rate of q units per unit time, and to which water is supplied at the rate of mass m per unit time at the initial temperature of the system (taken to be zero) and removed at the same rate after perfect mixing.

If T is the temperature of the water in the enclosure at time t after switching on the heating current, its initial temperature being zero, it satisfies the differential equation:

$$M\frac{dT}{dt}+mT=q \quad . \ . \ . \ . \quad (1)$$

and the solution of this for which $T=0$ when $t=0$ is:

$$T=\frac{q}{m}(1-e^{-mt/M}) \quad . \ . \ . \quad (2)$$

Thus, the temperature rises exponentially to the value q/m and, q being known, m is found immediately. For example, taking 2·24 deg. Cent. as the maximum rise in temperature in the curve of Fig. 2 for 45ft, and 133W for the power, gives $m=14$ c.c. per second.

Next, it is necessary to discuss how far this simple theory is applicable to the practical case. Departures from it arise in three ways, namely, imperfect mixing of the water, time lags in the measuring apparatus, and loss of heat to the surrounding rock. Of these the last-mentioned is important only for very slow flows and will be discussed in section 5.

It appears from eqn. (2) that m could be estimated, not merely from q/m but from the time constant M/m of the exponential. In the present apparatus, however, the temperature measurement is made by a thermistor

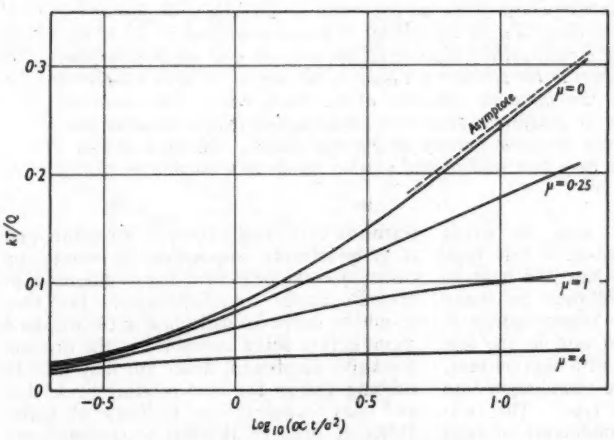


Fig. 3—Measurement of slow water flows

which (in order to avoid mechanical shocks) is not in contact with the brass body of the heater but is separated from it by an air film. This introduces a considerable time-lag into its readings and so the exponential rise in the practical curve of Fig. 2 is determined by this time lag as well as by M/m. This time lag does not affect the results in any way—its only disadvantage is that it extends the time necessary to make a reading. It is possible to reduce this time lag greatly so that a measurement may easily be completed in five minutes.

The effect of imperfect mixing may be important, and its amount can only be disclosed by some form of calibration. For example, in some laboratory experiments on another type of head it was found that with a known flow of 6·5 c.c. per second past the head the value of the flow calculated from the temperature rise was 4 c.c. per second. Thus, as would be expected, the instrument gives an underestimate of the flow because of imperfect mixing.

(4) Field Measurements

Fig. 2 shows the results of measurements in the hole mentioned in section 1 at depths of 100ft, 45ft and 20ft, with the seals partially inflated. In each case the heater power was $133W$ so that the flow, which is presumed to be up the hole, is approximately 14 c.c. per second at 45ft and 100ft and 5 c.c. per second at 20ft. Runs at 53ft and 100ft with the seals fully inflated showed no measurable movement of water across the hole.

This hole passes through a series of basalt flows which in some portions are highly vesicular and much decomposed, while other portions are massive and fresh. The results suggest that water is flowing up the hole from some level below 100ft and out through (at least) two fissures, one above 20ft and one between 20ft and 45ft. This is consistent with the fact that water is lost from the hole when it is completely sealed. The rate of fall of water when the hole was sealed was estimated at about 3ft per minute, corresponding to a flow of 15 c.c. per second in agreement with the figures given above for the water flow. Unfortunately, the hole became blocked before further measurements to locate the source and outlet of the water more precisely could be made, but it is clear from the results given and others obtained on a preliminary survey that this could have been done quite readily.

(5) Measurement of Thermal Conductivity and Slow Water Flows

The theory is that of radial flow of heat outwards from a circular cylinder of radius a. The region outside this cylinder is supposed to be rock of thermal conductivity k, density ρ, specific heat c, and diffusivity $\alpha = k/\rho c$. The region inside the cylinder is supposed to contain mass M_1 per unit length of a perfect conductor (the equivalent of the brass head and well-stirred water) of specific heat c_1 to which heat is supplied at the rate Q per unit length per unit time. Any consistent system of units, engineers' or c.g.s., may be used. The whole system is supposed to be at zero temperature at time $t=0$ and the flow of water is expressed by the assumption that mass m_1 of water is supplied to the interior of the cylinder per unit length per unit time at zero temperature and that water is removed at the same rate after mixing.

The solution of this problem in conduction of heat is complicated and will be given elsewhere* and only some numerical results from which calculations can be made will be presented. They involve three-dimensionless parameters:

$$\tau=\frac{\alpha t}{a^2},\ C=\frac{2\pi a^2\rho c}{M_1c_1},\ \mu=\frac{m_1a^2}{\alpha M_1} \quad . \ . \quad (3)$$

* *Aust. J. Phys.* (in press)

Of these, C, which depends on the relative heat capacities of the heater and the rock, does not affect the results greatly; under normal conditions its value lies between 1 and 2 and it is taken to be 1 in the calculations of Fig. 3.

μ is proportional to the rate of flow of water, and $\mu=0$ gives the case of no flow.

In Fig. 3 values of kT/Q, where T is the temperature measured within the hole at time t after switching on the heater current, are plotted against log $(\alpha t/a^2)$ for various values of μ. In the case $\mu=0$ (no water flow) it can be shown that for large values of the time the temperature T is given approximately by:

$$\frac{kT}{Q}=\frac{1}{4\pi}\ln\frac{2\cdot25\alpha t}{a^2} \quad . \ . \ . \quad (4)$$

This asymptote is shown dotted in Fig. 3. It appears that the slope of the curve of T against log t gives an estimate of the thermal conductivity k. If there is any flow of water, however small, the temperature tends as before to a horizontal asymptote Q/m_1. If the conductivity of the rock is known from a laboratory measurement the amount of the water flow can be found immediately from an experimental temperature-time curve and Fig. 3 and, even if the conductivity is not known, it is theoretically possible by a more refined analysis to determine the water flow from such a curve.

To see the order of magnitude of water movement which may be detected in this way, consider a water-filled hole 4cm in diameter, in rock for which $\alpha=0\cdot01$ (units c.g.s., calorie, deg. Cent.). This gives $m_1=0\cdot031\mu$ c.c. per second, corresponding to a speed of water movement of $6\cdot8\mu$m per day. Since the curve for $\mu=0\cdot25$ in Fig. 3 is very different from that for no flow, it follows that movements of the order of a few feet per day should easily be measurable.

(6) Acknowledgments

We are indebted to the Hydro-Electric Commission of Tasmania for its interest and co-operation in this work; to Mr. A. Beck of the Australian National University for assistance with laboratory and field measurements, and to Mr. A. R. Oliver, of the University of Tasmania, for helpful discussion and suggestions.

Conditions of Failure in some Turbine Diaphragm Blades

By K. H. KHALIL, B.Eng., M.Eng., Ph.D., A.M.I.Mech.E.*

This investigation was made following the breakage of some diaphragm blades of a 20,000kW steam turbine working in a central power station having two other turbines of the same type. After 12,000 running hours this turbine was opened and examined for final delivery inspection. Some low pressure diaphragm blades were found badly torn at several places. Each broken blade piece started with two cracks about 40mm long near the root and tip at the downstream side of the diaphragm. The purpose of this investigation was to study the reasons of this failure with a view to preventing this effect in other diaphragms. It was found that the damage was mainly due to vibration and fatigue at the downstream thin edges of the aerofoil blades. The diaphragms, being stationary and comparatively robust, and the nature of the torn pieces, indicated that the type of vibration was not mechanical due to misalignment of the turbine shaft or unbalance of any of its components, but most likely due to the change in pressure at both faces of the aerofoil blade, being comparatively positive at the concave and negative at the convex side with respect to the ambient pressure in the stage. A vortex wake is thus formed downstream initiating vibration of the blade edge. The partition blades of these particular diaphragm discs were comparatively long with rather thin sections that encourage vibration causing fatigue and failure. Methods of overcoming this difficulty were also studied and applied to the new diaphragm discs.

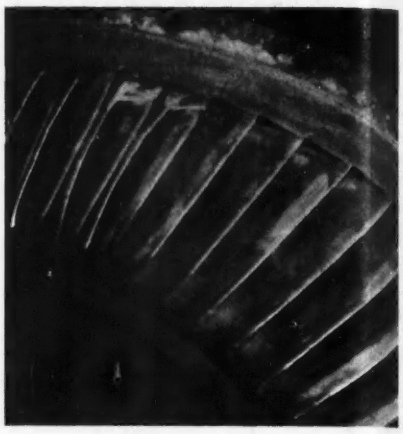
NOZZLE diaphragms may be either "built-up" or "cast-in." For high pressure sections of the turbine, the built-up construction is usually followed by many manufacturers. On the other hand, in turbines of medium power and in the low pressure stages of turbines with high outputs, the nozzle plates in the diaphragm are frequently of the cast-in type. The procedure adopted in the manufacture of such cast-in blades varies somewhat but generally they are made from sheet metal of uniform thickness which is first cut to shape and then curved in a press. After being formed to a shape of aerofoil character, and having the correct curvature at inlet and outlet, the blades are then embedded in a sand core which is to form the steam passage in the nozzles. Each blade end projects outwards from the core, so that when the molten metal is poured into the mould, the projecting edges will be surrounded; on freezing of the metal the blades become firmly held.

From the point of view of stress computation, this type of cast-in diaphragm forms an exceedingly complex structure, and it is practically impossible to obtain by calculation the deflection due to difference in pressure across the diaphragm. But they should be tested for deflection in the builder's shops before being assembled in the turbine. Excessive diaphragm deflection may lead to rubbing against the next rotating blade disc and may cause failure to both of them. Different rates of thermal expansions may also be a source of trouble with turbine diaphragms, namely, distortion due to temperature effects. If a change in the operating conditions is made quickly the diaphragm will respond to the new conditions of temperature more rapidly than the heavier casing and the difference in expansion may cause buckling of the partition blades unless sufficient allowance is made for such expansion. Long diaphragm blades may also fail if they are subjected to vibration caused by the synchronism of certain periodic disturbing forces with their natural frequencies of vibration. Breakage in this case occurs at the thin downstream portions of the blades which are subjected to flow variations and wakes initiating vibration. That was the mode of failure in the present instance.

Data of Turbine Diaphragms

Maximum rating	20,000kW
Revolutions per minute	3,000
Steam pressure at stop valve	550 lb/sq in
Steam temperature at stop valve	800 deg. Fah.
Condenser vacuum	28in Hg
Type of turbine: condensing impulse with single pressure stage	
Number of stages	14
Total number of hours run	12,000

All diaphragms are in halves and are held in position axially and radially by means of a tongued and grooved joint around the periphery and at the horizontal division, the arrangement being such that the top half casing with its half-diaphragms can be removed without, in any way, disturbing the half-diaphragms in the lower portion. The central opening in the diaphragms is fitted with yielding labyrinth packing closely embracing the shaft.



Figs. 1 and 2—Fractured blades: the fractures started with two cracks from right to left near the top and root at the downstream side of the blade. These cracks joined together with a vertical crack as indicated by chalk lines

Conditions of Diaphragm Failure

Fortunately the defective diaphragms were discovered when the machine was opened up for examination. It is quite possible that if the examination had been delayed for any reason, a very serious accident would have occurred. The blades of the two diaphragm discs Nos. 12 and 11 were found badly torn at twenty-nine different blades distributed around their peripheries as shown by the photographs reproduced in Figs. 1 and 2, respectively.

The fractures started with two cracks from right to left, near the tip and root at the downstream side of the blade. These cracks joined together with a radial crack, as

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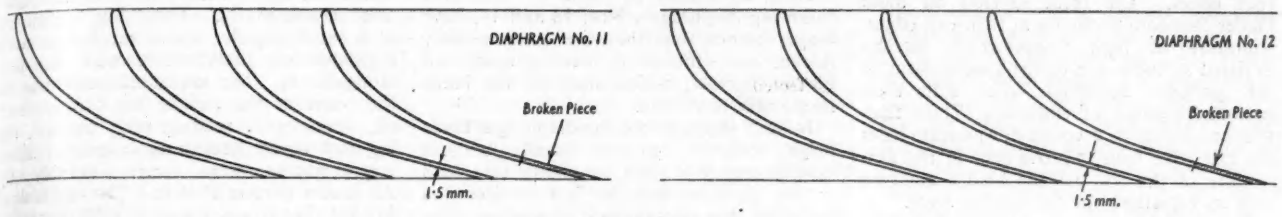
indicated by chalk lines in the same Figs. 1 and 2. The average width of these strips is 40mm, while the length varies up to 140mm for diaphragm No. 11 and 200 for diaphragm No. 12. A few of the torn pieces, found hanging in their positions, were just about to separate.

Other diaphragm discs were checked and found in good condition. The rotor and moving blade discs were also examined and nothing wrong was detected. The two diaphragms in which failures had occurred were further inspected for warping or distortion due to heat stresses, but found to lie exactly in a plane normal to turbine axis. The blades of each diaphragm were then measured and drawn to scale, as shown in Figs. 3 and 4.



Figs. 3 and 4

Necessary data for analysis of flow passing through the two nozzle diaphragms is given in Table I, together with data of the neighbouring diaphragms Nos. 10 and 13 for comparison. The width of diaphragm No. 11 is 75mm and its height is 118mm at entrance and 145mm at exit ; the width of diaphragm No. 12 is 78mm and its height is 166mm at entrance and 215mm at exit. The change in height is for the increase in specific volume of steam and is made gradual at both the tip and root sides of the blade. Minimum blade thickness is 1·5mm at the exit or downstream side of the blade for both diaphragms.

Diaphragm No. 11 works between the pressure limits 13·17 lb and 8·28 lb per square inch absolute, i.e. with a pressure drop ratio $rp = 0·63$ (higher than the critical).

Net adiabatic drop in the stage (nozzles and blades) = 1122 − 1097 = 25 B.Th.U.

Theoretical adiadatic drop (from $I-\phi$ chart) = 1122 − 1089 = 33 B.Th.U.

Stage efficiency $= \frac{25}{33} = 75·7$ per cent.

Theoretical jet velocity from diaphragm No. 11 $= 224\sqrt{33} = 1290$ft per second.

When effects of nozzle efficiency and approach velocity were taken into consideration the net jet velocity becomes 1287ft per second, as given in Table I, which is a subsonic velocity.

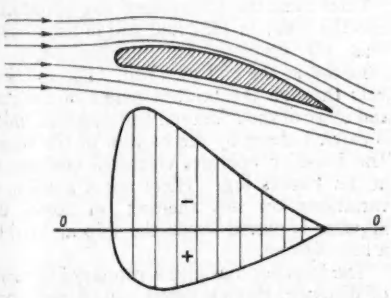


Fig. 5

The steam flow area of each diaphragm is checked by considering the actual dimensions measured, as compared with actual flow passing through the diaphragm from the stop valve.

Net throat width 10·28mm.

Height of diaphragm blades at exit 145mm.

Number of blades in the row = 80.

Therefore

Area of flow = 10·28 × 145 × 80 = 119,200 square millimetres = 1·28 square feet and volume of steam passing per second = 1287 × 1·28 = 1647 cubic feet per second.

On the other hand, actual steam flowing through this diaphragm is equal to total steam consumption taken from the boiler minus that extracted by the three previous bleeders, which amounts to 9·03 tons per hour.

Therefore

Net steam passing through diaphragm 11 per second

$$= \frac{(69·5 - 9·03) \times 2240}{3600} = 37·65 \text{ lb per second}$$

Specific volume at downstream edge of the diaphragm = 46 × 0·957 = 44 cubic feet per pound.

Therefore

Volume of steam passing per second = 37·65 × 44 = 1660 cubic feet per second,

which checks fairly well with that obtained from the velocity side, based on the actual dimensions measured from the diaphragm after the accident.

The same procedure was followed for diaphragm No. 12 and good agreement was also found between the calculation and actual dimension.

Both diaphragms were then checked for any warping or twisting, but nothing was found in any of them. The two diaphragms work in vacuum and rather low temperatures in the range of 84·5 deg. and 97 deg. Cent. for diaphragms Nos. 12 and 11 respectively. At part loading the change in these temperatures is not very great, which excludes the possibility of a thermal shock taking place at a sudden change of load ; this would have caused buckling effects in some of the blades, but nothing of the sort was observed.

Flow in Curved Passage Between Diaphragm Partition Blades

It is well known that the flow in bends or between curved blades cannot be considered as a rotation in which the velocity increases towards the outer periphery. On the contrary, the velocity is always greater at the smaller radius, i.e. at the back or convex side of the blade. In this case there is in addition a compression at the concave side of the blade due to centrifugal effect and diminution of the flow velocity, as a result of which the velocity on this side is still further reduced.

On the other hand, if each blade is treated as a single aerofoil or within a cascade of aerofoil blades placed in the stream there will be a difference in static pressures across the faces of each blade, as shown in Fig. 5, and the sum of these pressure differences is equivalent to the centrifugal effect mentioned above. Accordingly since the weight of steam deflected per unit time is increased with increase of pitch the load due to centrifugal force is also in creased with pitch, but up to a certain limit, where the stream flowing does not follow the shape of the passage.

The comparatively high pressure stream near the concave face tends to spread in a radial direction, but is prevented by the closed ends of the flow passage at top and bottom. However, friction at the top and bottom surfaces of the passage slows down the stream in its neighbourhood, reducing the centrifugal force and the consequent pressure rise. Radial flow along the partition then takes place both inward and outward with the formation of a pair of symmetrical vortices which continue in the fluid after it leaves the bend. The issuing flow is therefore distorted by the time the exit is reached. The flow direction is shifted towards the convex back of the blade at the root and tip and

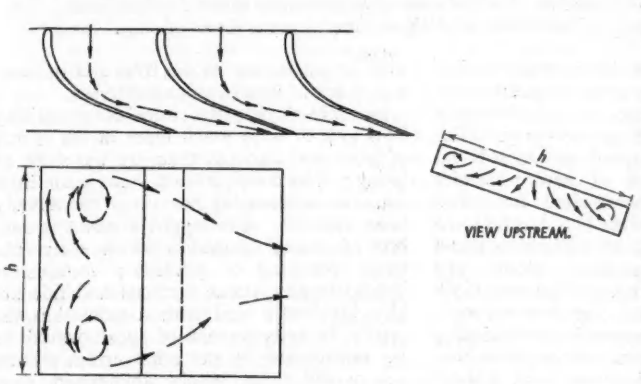


Fig. 6

Table I

Diaphragm	No. 10	No. 11	No. 12	No. 13	Units
Total heat	1,150	1,122	1,097	1,072	B.Th.U.
Pressure at inlet stage	19·72	13·17	8·28	5·07	Lb/sq in
Temperature at inlet stage	226·5	207	184	163·5	Fah.
Dryness fraction	0·993	0·975	0·957	0·943	—
Jet steam velocity	1,260	1,287	1,292	1,514	Ft/sec
Steam flow area	79,200	119,200	179,200	272,000	Mm sq
Inlet angles to nozzles	130	130	135	100	Deg.
	110	105	95	—	Deg.
Outlet angles	14	14	14	13	Deg.
Average pitch	48·1	48·7	49·3	40·6	Mm
Diaphragm blade thickness at outlet	1·5	1·5	1·5	1·5–3	Mm
Throat width	10·15	10·28	10·43	12·9	Mm
Number of channels	80	80	80	68	—
Height at outlet	97·5	145	215	310	Mm

toward the concave face at mid-height, as illustrated by the sketch in Fig. 6.

Vibration of Partition Blades

The effect of the turbulent wakes downstream from the nozzle edges is to reduce slightly the nozzle efficiency; but, more importantly, it creates a region of fluctuating velocity at the downstream side of the blade due to the existing vortices near the tip and root edges. The force exerted on these blades therefore fluctuates at their exit edges. Vibration of high frequency is thereby initiated in them due to the synchronism of this periodic disturbing force with their natural frequency of vibration. These fluctuations, however, decrease downstream from the exit edge with improvement in the uniformity of the jet, but the blades must be able to withstand the fluctuating force.

It may be of interest to mention that these vibrations can be, and generally are, transfered to moving blades adjacent to them, and unless they are strong enough to resist fatigue they may fail too. This is because the wakes of the diaphragm blades create a flow field of regularly varying intensity in the entrance to the moving blade row only a short distance downstream and then the moving blades likewise produce a similar field, except that it is rotating about the turbine axis at the entrance to the following diaphragm blades, and so on for the rest of the turbine.

It may be added that partial admission in the first few stages of an impulse turbine tends to cause vibration of the blades and may affect the continuity of steam flow throughout the rest of the turbine stages in a way that helps vibration and failure of blades.

The question still remains why a particular pair of diaphragms failed while the others and all the moving blade rings remained unaffected. The answer lay in weakness of blade material at certain sections of these blades. The blades are longer than those of any previous diaphragm while having the same thickness at the downstream side—1·5mm, as shown in Table I. The next following diaphragms Nos. 13 and 14, have longer blades, but they are comparatively thicker and stiffened by riveting every two blades together, which shortens the blade length able to vibrate.

In such stages where the diaphragm blade height becomes greater, usually without notable change of pitch, the greater total load on the partition and the flow vortices and turbulent flow downstream necessitate some increase in the thickness and/or strengthening the partition blade groups by tying every two blades together with lashing wires or riveting. Lashing wires connecting adjacent partition blades have a stiffening effect. The amplitude of the vibrating assembly can be measured beforehand and the load required to produce static deflection corresponding to this amplitude is found and from it the stress in the structure can be calculated, if desired.

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Ships' Speed Measurement

D. A. SENIOR, M.A., A.M.I.E.E.*

New methods of measuring the speed of ships are being developed in various parts of the world. Some of the methods show promise of leading to speed logs which will be extremely accurate. Whilst these new logs may benefit the warship, which has special problems, the advantage in ordinary navigation is limited by other errors which are unavoidable. This article examines the various sources of error and concludes that, so far as merchant ships are concerned, the future of the new logs will depend on cost and ease of maintenance rather than accuracy. The point is clearly of importance to designers and manufacturers of ships' logs.

RECENT advances in instrumentation have enabled many of the old quantities to be measured in new ways, sometimes with a startling improvement in accuracy. The measurement of the speed of ships is no exception. A number of new principles are being actively investigated for naval use in Great Britain and the U.S.A., and some of them show promise of leading to speed logs which are very accurate indeed. The problems of the Royal Navy differ from those of the Merchant Navy in a number of ways, but those who are interested in the equipping and navigation of merchant ships, for whom this article is chiefly intended, may wonder if these new advances will have any application outside the R.N. The aim of this account is therefore to compare the new methods with the old, and then, by considering the various errors which are involved in navigation, to discover how much benefit the increased accuracy of the new logs is likely to confer. The Royal Navy has of course problems of its own in weapon control which make special demands of the log and account for some of the interest in new techniques; these will be omitted from the argument. So also will the use of radio aids to navigation, for the basic need to be able to navigate with no outside assistance, from star or man, will be felt as long as ships put to sea.

In early days, ships were comparatively slow and so were much more at the mercy of wind and currents than are the ships of today; they could, indeed, have made little use of an accurate log even if one had already been invented. The logged distance is only one of several quantities which enter into dead reckoning of position; movements due to leeway, ocean currents and tide are also involved; and with a slow ship the errors in measurement of speed would be far outweighed by the other errors (Noah, one would infer, wisely abandoned dead reckoning and relied entirely on aerial reconnaissance). As ships became faster, the demand for accurate speed measurement became more pressing, but it was many centuries before sail gave way to steam. This perhaps accounts for the long vogue of the log chip. The log line, log chip, and hour glass adequately met the needs of sailing vessels and were superseded only after the advent of steam propulsion. They were used in the following way: the log was put overboard with a knotted line attached, usually every hour, and as the log was left further astern the line was paid out until a piece of bunting which was attached to it showed that the log was clear of the ship's wake. At this point the hour glass was inverted and when the sands ran out 14 or 28 seconds later it was a junior officer's job to count the number of knots and "parts of a knot" which had been drawn out. To-day the words "log" and "knot" are all that remain.

The story of the modern log began in 1802 when Edward Massey invented a log which was towed behind the ship and registered continuously. The "log" consisted of a small impeller whose revolutions were registered on dials which were mounted alongside it. The whole assembly was in the water at the end of the towing line; so, whenever a reading was required, the log had to be hauled on board. Various improvements were made, notably by Alexander Bain in 1846 and Thomas Walker in 1861, but it was not until 1878 that a log was invented which could be read *in situ*. This was the Walker Cherub in which the impeller rotated the cable, the dials being mounted on the taffrail where the cable was held.

Nearly 50 years later, Kempf invented his resistance log, which indicated speed (as opposed to distance run) by measuring the drag of a conical body towed behind the ship. Soon afterwards, in 1930, the Walker Patent Log combined speed and distance indication by measuring both the drag and the rotation of a specially designed impeller.

In the meantime other developments were afoot. The towed logs have one great drawback: they must be hauled in whenever the ship goes astern or reaches harbour; they can also be a source of trouble in tight manœuvres. To overcome this drawback, logs were devised which could be left in position at all times. The new logs were fitted in the ship's bottom and so were called "bottom logs." The first log of this kind to be used in the Navy was the Forbes log, which appears to have been developed about 1911 and was introduced into the Fleet during the 1914–1918 war. It consisted of a tube projecting from the hull, having an opening facing forward at the bottom end and an opening facing aft at the top. Between the openings an impeller was mounted which was rotated by the upward flow of water in the tube resulting from the forward motion of the ship. The impeller was attached to a vertical shaft which operated electrical contacts each time the impeller had performed a set number of revolutions, and these actuated distance indicators.

Later came the Chernikeef log introduced into the Navy in 1922 and still in use to-day. This log employs an impeller which is mounted at the end of a rod. The rod projects through the bottom plates of the ship and clear of the frictional belt of water which is carried along by the motion of the vessel. The impeller operates electrical contacts as in the Forbes log. There are a number of variations on this theme; in some, the impeller is placed inside the ship and fed by a tube system.

The impeller logs give a primary indication of distance, though speed can, if necessary, be derived from the rate of rotation. This was done in the Forbes log by means of a tacho-generator and in the Chernikeef by counting the distance impulses received in small fixed periods of time. However, the need was felt for a log which gave a primary indication of speed, and during the 1920s pitôt type logs, which have this property, were coming into use. The Pitometer log, the type of pitôt log used by the Navy, carries dynamic and static orifices in the end of a

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rod which projects through the ship's bottom as does the rod for the Chernikeef log. The dynamic orifice is arranged to face the direction of flow of the water and measures the pressure head set up by the relative motion of log and water, whilst static orifices are arranged sideways on to the flow so as to measure the static head. The difference between the pressures in the dynamic and static orifices is measured by means of a bellows arrangement and is basically proportional to the square of the speed. Another type of pressure log, the Bow Log, was already achieving popularity in Germany before the war. This log works on the pitôt principle, but the dynamic orifice is situated in the bow of the vessel. Two static orifices are situated on opposite sides of the ship some way back from the bow at a position where the effect of water flow around the ship is a minimum. Logs of this type were installed in " Europa," " Bremen," Scharnhorst " and " Gneisenau," and great claims have been made for their accuracy.

It will be seen that each improvement has involved some extra complication, and this trend has continued. Since the recent war an electromagnetic log has been produced in which the motion of the sea-water, a conductor, through an alternating magnetic field generates an alternating electrical potential in the water. The potential is picked up by means of electrodes and amplified to give a very accurate indication of water speed. This system has the advantage that the indication varies linearly with speed, and so does not suffer from the same loss of accuracy at low speeds, as do the pitot devices where the indication varies with the square of the speed ; and furthermore there are no moving parts, as in the impeller logs. Experiments have been carried out with electrothermal devices, in which the heat loss from a member placed in the water stream gives an indication of speed. An acoustic method has been suggested, in which sound would be transmitted " upstream " (i.e. towards the bows) and " downstream." The difference in velocity of the sound with and against the water stream would lead to differences of phase in the signals picked up by suitably placed receivers, and the phase difference should give an accurate measure of water speed. Various other suggestions have been put forward.

The advantages of the new methods (that is, those which have been developed since the advent of pitôt and impeller logs, which now hold the field as far as bottom logs are concerned) have to be regarded from two points of view : first, the accuracy of the indication, and secondly, their cost, reliability and ease of maintenance. There is little doubt that greater accuracies will be achieved. The probable error of the pitôt and impeller logs seems to be somewhere between 1 and 2 per cent except at low speeds, when errors of 1 knot can occur ; the new methods are capable of refinement to give accuracies far better than this, especially at low speeds, the errors perhaps being as little as 0·1 knot. On the face of it this might seem to lead inevitably to an improvement in the accuracy of navigation. A study of other sources of error suggests, however, that the improvement would be slight, and it is the writer's opinion that the decision will largely be governed by questions of cost and ease of maintenance. The reasons for this view are bound up with a number of limitations which all bottom logs have in common.

Limitations of Bottom Logs

All these logs—impeller, pitôt, electromagnetic, thermal and acoustic—aim at measuring the speed of the ship relative to the body of the water surrounding it, but none of them is capable of carrying this out directly. They can measure only the relative water velocity at the point where they are placed. This velocity is obviously related in some way to the speed of the ship, but it depends on other factors : the flow of water around the hull takes on different patterns at different speeds and this inevitably leads to departures from the basic linear or square law, so a correction must be applied ; the relationship between true ship speed and log indication varies with marine growth, for this also influences the flow conditions ; sideways movement of the ship (due to wind forces, for example) can have an effect on the reading of the log ; and finally, variations arise especially in heavy weather, from the rolling, yawing and pitching of the ship and from the effects of waves and turbulence. In practice the log is calibrated, when possible, during runs on the measured mile. An attempt is made to minimise the effect of leeway on the reading of the log by designing the measuring part to give an indication so far as possible independent of yaw angle—that is, the angle between the axis of the ship and the direction of water flow at the log. At best, however, this leads to measurement of the distance travelled relative to the water but not of the angle between the ship's mean heading and the course made good. This angle, or the leeway which determines it, must therefore be estimated and, in high

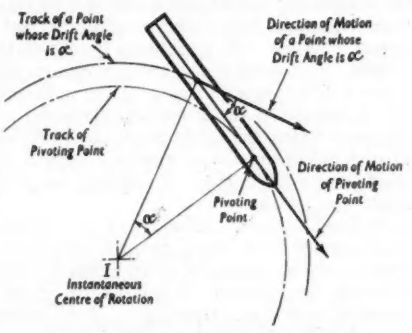
Track of a Point whose Drift Angle is α
Direction of Motion of a Point whose Drift Angle is α
Track of Pivoting Point
Direction of Motion of Pivoting Point
Pivoting Point
α
α
I
Instantaneous Centre of Rotation

Fig. 1—Effect of drift angle in turning

wind conditions, this can never be done with certainty. Again, even if leeway is estimated with accuracy and the log is arranged to indicate water speed independently of the yaw angle, there still remains a major source of error—the movement of the water itself over the sea bed.

Further error arises when the ship is under helm, a condition of greater interest to the R.N., but still important to merchant vessels if a zig-zag course is to be steered. The pattern of the water flow around a ship which is turning is not known exactly, though it is known that the active parts of the log (the orifices or the impeller, for example) would have to be situated impracticably far below the ship's bottom if they were to operate in water undisturbed by the motion of the ship. Some idea of the behaviour of the water can be gained, however, from the known behaviour of the ship itself, which is illustrated in Fig. 1. Once the ship has settled down to a steady rate of turning, it acts as though it were rigidly connected to a point *I* some distance out on the beam. A line from this point at right angles to the fore-and-aft line, or axis, of the ship meets the axis at the pivoting point *P*, which is generally near the bow. The pivoting point moves in a direction which lies along the axis of the ship, but any other point in the ship moves in a line making an angle with the ship's axis. This angle (α in Fig. 1) is known as the drift angle, or, in gunnery, the slip. There is little doubt that the sideways movement of the ship at all points except the pivoting point will involve a more rapid, compensating movement of water in the opposite direction beneath the keel. If this is so, the direction of water movement relative to the log will make an angle with the axis of the log—a yaw angle—which is even greater than the drift angle there. It is extremely difficult to build a log which gives a reading entirely independent of yaw and in practice the pitôt log over-reads and the impeller log under-reads if the yaw is great enough. If, therefore, the log is situated at any point other than the pivoting point (and this is inevitable since the pivoting point itself moves as the ship goes into a turn and varies slightly with the rate of turn), then not only does the log give a false reading of the magnitude of its velocity relative to the body of the water around the ship, but it fails to indicate its own true direction of motion.

The errors which arise from leeway, water movement over the sea bed and turning of the ship are all independent of the accuracy of the log and clearly set a limit to the log's " useful " accuracy. Before an attempt is made to assess this useful accuracy, two important sources of error—leeway and water movement—will be examined in greater detail.

Leeway

The movement of a ship in a direction at right angles to the fore-and-aft line brought about by a wind blowing at some angle to this line is an extremely difficult quantity to estimate. It depends on the bearing and strength of the wind, the speed of the ship, the state of the sea, the individual peculiarities of the ship, and possibly to a greater extent than any of these the method of the helmsman. The problem in the R.N. is more difficult than that in the merchant fleet as the navigating officer in the Navy does not generally serve for so long in the same vessel. In view of this, information about the behaviour of each ship in the Navy is entered in the Navigational Data Book so that the navigator may have the benefit of the experience of his predecessor. This system, at present the only practicable one, is demanded by the peculiarities of individual ships and suffers from the drawback that results cannot be averaged over a number of ships except in the mind of an experienced navigator, and then only in a general way.

The response of a particular ship to wind is derived in the following way. The true position of the ship at morning and evening is known, if conditions are favourable, from astronomical observation, and the dead reckoning position is calculated from course and speed. The error, after the effects of current and tide have been allowed for, is the effect of wind. Clearly the effects of the predominant current will tend to average out in time, so the errors (in assessing ship's response) arising from this course should be small. Moreover, runs with and against the tidal stream will eliminate this source of error. The effects of wind-induced water currents or surface drift will not cancel out, however, as this is a systematic error bound up with the same cause as the leeway itself. Now it is commonly assumed that the surface drift amounts to about one-fiftieth of the wind speed and sets (in temperate latitudes in the northern hemisphere) at 30 deg. to 40 deg. to the right of the wind. More or less may be allowed depending on the length of time the wind has been blowing. This is a very rough-and-ready rule, as will be seen

from the next section, and it seems that errors up to 1 to 1·5 knots in water speed can occur. This is of the same order as the leeway itself, so adds to the difficulty in estimating the leeway a given ship is likely to make under given wind conditions—the basic response to wind.

The other source of error in leeway estimation is the variation of technique from one helmsman to another. The "helmsman effect" can be assessed by comparing the ship's heading over a period with the course which the helmsman has been given to steer. The effect can be a large one: for instance the ship may tend to turn to windward and an inexperienced helmsman may correct for this incompletely, or too late if the wind is gusty, and steer a course 2 deg. to 3 deg. to windward of the required course; this may well counteract the leeway and result in the ship's boring to windward.

When a zig-zag course is steered, leeway is generally estimated on a basis of mean course. This avoids complications, but it can readily be shown that it is not compatible with the assumption, generally made, that leeway is proportional to the component of wind speed in a direction at right angles to the fore-and-aft line of the ship. The result (see Appendix I) is that if the wind blows at any angle to the mean course other than 90 deg., then errors in position accumulate along the mean line of advance as well as at right angles to it.

The master of a vessel in the merchant navy usually has a better chance of getting to know the behaviour of his vessel and the conditions in the area in which he sails as he is more likely to be plying the same route for a long period; but there must be few who would care to guarantee the accuracy of their estimation of leeway to better than half a knot in winds of strength 5 upwards.

Water Movements Due to Currents and Tidal Streams

Information concerning ocean currents is collected by the Marine Branch of the Meteorological Office almost exclusively from certain ships of the Merchant Navy who supply data of astro sights, land fixes, and dead reckoning position. Due allowance is made for leeway but naturally no allowance is made for expected current. The observations are carefully examined and many are rejected if, for example, the conditions for astronomical observation were in doubt, or the length of the day's run was such as to average out the effect of currents in too great an area. The information is published as three kinds of chart. These give Vector mean direction and rate, Current roses showing the variability of the current, and Predominant current direction and rate.

The Vector mean charts indicate the direction of water flow in the long run and so are useful to oceanographers in studying the theoretical aspects of current formation. They also help in the calculation of the probable course of derelicts, but the navigator derives most help from the rose and predominant charts. The Current rose consists of a circle through which arrows radiate in the directions of the sixteen subdivisions of the compass. Each arrow is of a length proportional to the percentage number of observations of current whose directions lie in the sector appropriate to the arrow in question. The length of the arrow is divided to show the proportions of currents in various ranges of rate. In each rose are given two figures. The upper one gives the total number of observations in the area to which the rose applies whilst the lower figure shows the percentage of the total number of observations which are less than ¼ knot. This added to the percentage of the arrows makes up 100 per cent. The published rose chart shows the area to which each rose applies as these are chosen to be of different shapes and sizes so as to separate the various basic current trends in the general circulation.

The Predominant charts are based on a rectangular grid system, and are computed by examining all the observations of current in each rectangular area in turn so as to find out in which direction the largest number of currents set. This is done by counting the number of currents in a series of twenty-four sectors of 90 deg., round the compass, each one being shifted 15 deg. from its predecessor. The number of currents is counted for the sector 0 deg. to 90 deg., 15 deg. to 105 deg. and so on. The predominant current is taken as the bisecting line of the quadrant containing the largest number of observations or possibly as a line 5 deg. or 10 deg. on one side of the bisector if the distribution of currents within the sector is uneven. Not infrequently there is a secondary predominant direction in addition to the primary one. To produce the final chart for publication it is necessary to smooth the data in each of its aspects: direction, rate, and constancy. Often, insufficient data in one rectangle lead to fictitiously high constancy of the currents (the number of observations of currents in the predominant quadrant expressed as a percentage of the total number of observations); on occasion the results may not fit into a coherent picture when compared with those in adjoining rectangles. When the smoothing, particularly of small variations of the average rate of the currents, has been carried out, the information is presented in the form of flow-lines of various lengths, the thickness of the flowline-arrows indicating the constancy. Figures of average rate of current are placed between successive arrows.

In day-to-day navigation, the Predominant and Current rose charts are, or should be, used in conjunction, the Predominant chart showing the direction of the current chiefly recorded and its average rate. The degree of probability that the current direction shown on the chart will be the one experienced is indicated by the thickness of the arrows, and it is nowhere 100 per cent.; so in no place can the current be predicted with absolute certainty. In certain areas 85 per cent or even 90 per cent may occur but it is generally much lower. In areas where the constancy is less than 50 per cent, the total number of currents flowing in all other directions exceeds the number flowing in the predominant direction, but more current will flow in the predominant than in any other single direction so it is still worth while to take account of the current. How far the navigator is likely to be wrong in assuming that the predominant current is the one he will meet is indicated by the chart of current roses. These show the maximum rate of current that has been observed in the region and the extent to which the direction has been known to differ from the predominant one.

The variability of currents in the open ocean arises almost entirely from variation in the strength or direction of the wind, but the formation of currents even here is very complex and not yet fully understood. There is, for example, a secondary effect producing a slope of the sea surface and hence a gradient current in roughly the same direction as the primary wind current or drift. Nearer to the coasts, the currents are primarily gradient currents due to a slope in the sea surface near a coast line. The slope is directly or indirectly produced by wind, directly as when a wind blows obliquely across a coast line and drives the water away so establishing a gradient despite the up-welling of sub-surface water, or indirectly as when water is piled up in restricted waters due to currents generated in the open ocean. The Gulf Stream, for example, owes its origin to the head of water built up in the Gulf of Mexico by the Equatorial currents of the Atlantic.

The important question is thus: to what extent can the variations of current be deduced from a knowledge of the winds which have produced them? The answer seems to be: only very roughly. A time lag exists between the onset of wind and the maximum current resulting from it. There is also a time constant of decay of a current once it has been established. For practical purposes, the times are of the order of a day. Owing to the Coriolis force and other effects which are still being investigated, the current sets at a direction to the wind (about 30 deg. to 40 deg. to the right in the northern hemisphere, and to the left in the southern hemisphere). There is a latitude variation and an increase in the current rate with time as the gradient current comes into play. The magnitude of the variation in rate is illustrated by the fact that there is no part of the ocean where the current may not attain a rate of 1 knot and in most regions this is exceeded at times. The charts show also that the observed rate can exceed the predominant by a factor of two, or even more in regions of less constant current. Rates exceeding 2 knots are observed over considerable areas for the most part throughout the year. Rates exceeding 3 knots occur in many places, the East African coast current reaching 7 knots, the Gulf Stream 1 knot, Kuro Shio and Agulhas current 5 knots, and the East Australian coast current 4 knots. On the other hand, there is no region where rates less than ¼ knot are not sometimes experienced.

Study of the charts suggests that the order of error in estimating the current may well be 1 or more knots even in the open ocean. In coastal regions the tides augment the possible errors.

Information regarding tidal streams is computed mostly from observations by H.M. Surveying Ships. It is published by the Hydrographic Department of the Admiralty in the *Atlas of Tides and Tidal Streams, British Islands and Adjacent Waters* and in a series of *Pocket Tidal Stream Atlases* of frequently used waterways. Tables of tidal streams are also printed on navigational charts. Further information is published in *Sailing Directions* and in an H.D. publication, *Tidal Streams of the Waters Surrounding the British Islands and Off the North and West Coasts of Europe*. In observing the speed and direction of the tidal stream the surveying ship anchors; at the appropriate times a pole with a draft of 30ft is allowed to drift with the tide for a measured time. The movement is measured by paying out a line connected to the pole whilst the direction of the stream is determined by taking bearings on the pole. The displacements in two perpendicular directions are plotted to a time base and each follows a distorted sine wave with two complete cycles in twenty-four hours fifty minutes. The mean value of the curve is rarely zero on account of the predominant current and local temporary wind effects. The non-oscillatory portion is used in the compilation of current charts and the oscillatory portion is published as tidal data. The accuracy of the observation is such that the figures show a scatter of only ±0·1 to 0·2 knot in British waters. Errors appear as quite a high percentage of the stream, for

speeds greater than 2 or 3 knots are encountered only in comparatively narrow waters; over most of the North Sea, for example, the maximum speed is less than 0·5 knot. The absolute error is, however, a small one. Further error may arise from the method of interpolation, for the assumption is made that the rates vary linearly with the mean tide at Dover for the day. This is an approximation which works satisfactorily away from the shore. Inshore, however (where the speeds of the streams are, moreover, higher), the approximation is less accurate on account of the variation in the section of the channel with the height of the tide. In the regions where dead reckoning is likely to be relied on, it is not to be expected that interpolation errors will increase the overall errors beyond ±0·3 knot.

The figures given so far apply to the waters surrounding the British Isles. In other parts of the world observations are fewer and in many areas the tidal stream system is far more complicated than it is around the British Isles. Especially difficult are those large areas—notably the shores of the Pacific Ocean—where the diurnal components of the tides and of the tidal streams are large. The streams are not then proportional to the range of the tide at some neighbouring port as in European waters. Errors of 0·5 to 1 knot may, therefore, be encountered on occasion. Usually, though, the errors in estimating tidal stream are small compared with those due to drift currents caused by past and present winds. Taking all causes into account, a probable error of 0·3–0·5 knot seems to be the most reasonable estimate.

TABLE—*Probable Errors After Travelling 100 Miles*

Course	Ship's speed, knots	Time for 100 miles, hours	Probable errors, miles								
			Log error	Compass error	Turning error	Currents drift tides	Leeway				
							Wind force 10	Wind force 8	Wind force 6	Wind force 4	Wind force 2
Steady	8	12·5	1·3	0·3	—	4	11	8	5	3	1
	16	6·25	1·3	0·3	—	2	6	4	3	1	1
	32	3·2	1·3	0·3	—	1	3	2	1	1	0
Zigzag	8	14·7	1·3	0·3	0·2	5	10	7	5	3	1
	16	7·4	1·3	0·3	0·2	3	5	4	2	1	1
	32	3·7	1·3	0·3	0·2	1	3	2	1	1	0

Useful Accuracy

To sum up, navigational accuracy is limited chiefly by leeway and the movement of water over the sea bed. It also depends on the accuracy of the compass and, if a zigzag course is pursued, on the extents to which the ship "skids" and the log is affected during turns (see Appendix 2), but the errors arising from these causes are relatively small. A table of probable errors has been prepared and is presented below.

The following probable errors have been taken: log 1·3 per cent (2 per cent standard deviation), compass 0·2 deg., currents, tides, &c. 0·3 knot. They are based on a careful examination of all sources of inaccuracy. Leeway errors are based on the estimate that leeway is proportional to wind component across the course the constant of proportionality having a mean value 0·075 and standard deviation 0·025. This is consistent with the estimates made by a number of experienced navigators with whom the problem has been discussed and with the occurrence of errors up to 1 knot in some circumstances. The errors are lower for a zigzag course than for a steady course. This arises from the fact that in the former case the position error is shared in directions along and across the mean course, so that the square root of the sum of the squares of travelled. If the log error were eliminated entirely the error would be $\sqrt{0\cdot3^2+4^2+3^2}=5$ miles. Even allowing for a considerable margin of error in the estimates on which the table is based, it is evident that the increase in accuracy of navigation brought about by a more accurate log is likely to be disappointing, to say the least. At low speeds, less than 4 knots, say, the errors of pitôt and impeller logs are greater, the former because the indication is proportional to the square of speed, so that very low pressures are involved, the latter because of friction troubles. Both those drawbacks are avoided if certain principles of measurement, e.g. electromagnetic, are employed, but it is at those low speeds that leeway and water movement errors are greatest also; so again the benefit may be swamped by the unavoidable errors.

Just how far the logs based on the new principles will score on the grounds of cost and ease of maintenance only the future can decide.

Acknowledgments

The writer acknowledges with gratitude the help he has received from numerous experts in the various subjects which this article involves. He wishes to mention particularly Mr. Maples (present-day logs), Mr. Wassell (the gyro-compass), Mr. Yearling (ship turning), Mr. Barlow (the measurement of ocean currents), Commander Suthons (tidal stream measurement), and Commander Hoare and Commander Rodwell (leeway estimation). He is indebted to the Admiralty for permission to publish this article.

Appendix I

The Accumulation of Errors Due to Leeway in Steering a Zigzag Course

As mentioned in the body of this article, the leeway, V_s, can be expressed as a function of the component of wind at right angles to course, V_w, by the equation $V_s=kV_w$, where k is a random variable normally distributed with mean $\bar{k}$; for medium-sized vessels, $\bar{k}\approx0\cdot075$ and standard deviation $\sigma_k\approx0\cdot025$. When the ship travels on a steady course at an angle ψ to the wind, the error in estimating the wind effect is:

$$(k-\bar{k})V_wT\sin\psi \text{ miles},$$

where T is the time involved. The mean square error, assuming all values of ψ equally common, is $\frac{1}{2}\sigma_k^2V_w^2T^2$, i.e. about $3V_w^2/V_s^2$ miles squared per 100 miles travelled for a medium-sized vessel.

When a zigzag course is steered, leeway is generally estimated on the basis of mean course. It can readily be shown that this is incompatible with the formula already given: suppose a ship steams from a point A to a point B, and then an equal distance to a point C, all at constant speed, and the wind blows at right angles to AC with velocity V_w. Then the wind effect calculated from the mean course is $\frac{2A}{V_s}kV_w$ in a direction perpendicular to AC, where A is equal to the distance AB. The wind effect calculated for the legs AB and BC independently and added vectorially is $\frac{2A}{V_s}kV_w\cos^2\frac{\widehat{BAC}}{2}$; there is a factor $\cos^2\frac{\widehat{BAC}}{2}$ which is unity only if A, B and C lie on a straight line.

If the wind blows at an angle other than 90 deg. to the mean course, errors will accumulate along the mean line of advance as well as across it. To determine the magnitude of the errors, it is necessary to know how many miles are travelled at any given angle to the main course. Suppose, for example, that a distance $y\delta\lambda$ is travelled in directions lying between λ and $\lambda+\delta\lambda$ to the mean course and that y is given by the expression $C\cos^2\lambda$ where C is some constant. Then if the ship's speed is constant, the mean rate of advance can be shown to be $8V_s/3\pi\approx0\cdot85V_s$. The wind effect for the courses lying between λ and $\lambda+\delta\lambda$ is $kV_w\sin(\psi-\lambda)\frac{y\delta\lambda}{V_s}$, where ψ is the angle between the wind direction and the mean line of advance. Resolving the wind effect along the mean line of advance and integrating to cover all values of λ between $-\pi/2$ and $+\pi/2$, the wind effect along the mean line of advance is:

$$\int_{-\pi/2}^{+\pi/2}kV_w\sin(\psi-\lambda)\sin\lambda\,.\,\frac{C\cos^2\lambda}{V_s}\,.\,d\lambda$$

$$=\frac{\pi C}{8}k\frac{V_w}{V_s}\cos\psi.$$

It can similarly be shown that the error across the mean line of advance is:

$$\frac{3\pi C}{8}k\frac{V_w}{V_s}\sin\psi.$$

Now the time taken is equal to the distance travelled divided by V_s, i.e.

$$\frac{1}{V_s}\int_{-\pi/2}^{+\pi/2}yd\lambda=\frac{\pi C}{2V_s}.$$

Dividing the wind effect by the time taken to develop it, the leeway along the mean line of advance is $\frac{kV_w}{4}\cos\psi$, and that across the mean line is $\frac{3kV_w}{4}\sin\psi$. This suggests that the best estimate of wind effect would be made if leeway were calculated on the basis of mean line of advance assuming that the

wind blew directly across this line, i.e. kV_w. This quantity would be multiplied by $\frac{\cos\psi}{4}$ to give the wind effect across the mean line of advance and by $\frac{\sin\psi}{4}$ to give the effect along it. If this is done, it can be shown that the mean square position error amounts to $2{\cdot}71\,\frac{V_w^2}{V_s^2}$ miles squared per hundred miles travelled, assuming all values of ψ are equally frequent. The figure is not very sensitive to the relationship between the miles travelled $y\delta\lambda$ on a given course λ to $\lambda+\delta\lambda$, and the course angle λ. For instance, if $y=C\cos\lambda$ the mean square position error is $2{\cdot}8\,\frac{V_w^2}{V_s^2}$; if $y=C\cos^3\lambda$, the error is $2{\cdot}69\,\frac{V_w^2}{V_s^2}$; for a steady course the value has been shown to be $3{\cdot}1\frac{V_w^2}{V_s^2}$.

If, on the other hand, the mean line of advance is used as the basis of calculation, then a systematic speed error will exist along the mean line of advance and random and systematic errors will exist in a direction at right angles to the line.

Appendix II

Plot Errors Arising From Turns

Surprise has been expressed that the figures given in the table for the position error due to turns should be so low. The theoretical basis for the figures is, therefore, presented in this appendix. By "plot" is meant a system in which the speed of the ship as indicated by the log is used in conjunction with the ship's heading as indicated by the compass to produce an automatic plot of the track of the ship relative to the water.

In such systems the assumption is made that the ship always moves in a direction along its fore and aft line, or axis. There are thus three sources of error :

(i) The log may be in error.

(ii) The gyro compass may be in error.

(iii) The ship may not be moving along its axis.

The log and gyro compass are both affected by the turn but it can be shown that the inaccuracy of the gyro compass from this cause inflicts little error on the plot during the turn. This source of error is therefore neglected in the following treatment. The

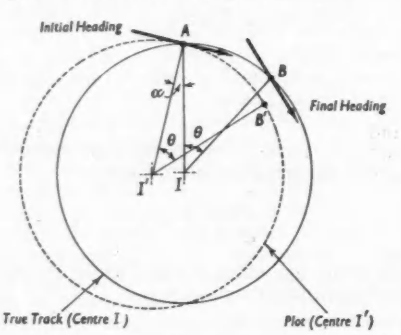

Fig. 2—True and plotted tracks of the log as a ship turns steadily in a circle

log, if of the pitôt type, will over-read on account of the lateral water flow beneath the ship, the degree of over-reading being some function of the drift angle at its location. The impeller type of log tends to under-read.

Suppose the log is initially at the point A in Fig. 2 and moves on a circle centre I, reaching the point B some time later. Then the ship's axis will initially lie at an angle $(\pi/2-\alpha)$ to the line AI, where α is the drift angle at the log, and will move through an angle θ equal to the angle AIB. The plot is made on the assumption that the log is moving in a direction lying along the ship's axis, i.e. at an angle α to the true direction of motion. The log indicates a speed V_L but is in fact moving with a velocity ΩIA where Ω is the rate of change of ship's heading.

Thus the plot consists of a circle centre I' where AI' is equal to V_L/Ω and the angle $I'AI$ is equal to the drift angle α. At the instant when the true position is B, the plotted position is B', the point B' lying on the circle centre I' and radius $I'A$; the angle $AI'B$ is equal to θ.

From the geometry of Fig. 2,

$$AB=2AI\sin\theta/2,$$
$$AB'=2AI'\sin\theta/2,$$
$$=2\frac{V_L}{\Omega}\sin\theta/2.$$

The position error in the plot, the vector BB' can readily be shown to consist of errors $2\left(\frac{V_L}{\Omega}-R\right)\sin\frac{\theta}{2}$ and $4R\sin\alpha/2\sin\theta/2$ in the directions shown in Fig. 3, R being written in place of AI. Of these errors, the first, which is due to the over-reading of the log, bisects the angle between the initial and final ship's headings ; the second, due to drift angle, lies very nearly at right angles to the first.

These errors are based on the assumption that the ship is turning steadily and are only an approximation for the errors which arise

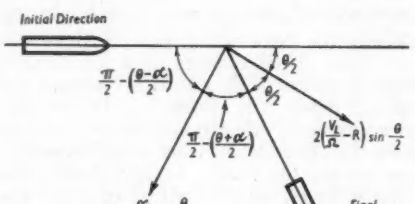

Fig. 3—Plot errors due to turning related to the initial and final directions of the ship's axis. The ship's heading changes by an angle θ

when a ship, moving on a steady course, goes into a turn and steadies on a new course. Comparison with a typical case for which the true curves of drift angle and virtual radius (AI in Fig. 2) against ship's heading are known, shows that the approximation seems to be a reasonable one. Thus the assumption can be made that, so far as errors in the plot are concerned, the full drift angle and rate of change of heading develop the instant when the helm is put over and disappear equally suddenly when the new heading is reached. On this assumption it can be shown geometrically that when a ship moves at constant speed and executes turns which differ in amount but are always made at a given rate of turn, the position errors due to the presence of drift angle during the turns cancel out if the initial and final ship's headings are the same and in any case the final error is small.

Consider, for example, the error introduced in changing from a course making an angle ϕ_1 with a datum to a course making an angle ϕ_2. Then the plot error due to the presence of drift angle during the turn is $4R\sin\alpha/2\,.\sin\frac{\phi_1-\phi_2}{2}$ where R is the distance from the log to the instantaneous centre of rotation during the turn and α is the drift angle at the log (see Fig. 3). The component of error resolved along the datum line is :

$$4R\sin\frac{\alpha}{2}\sin\frac{\phi_1-\phi_2}{2}\sin\frac{\phi_1+\phi_2}{2}$$
$$=2R\sin\frac{\alpha}{2}(\cos\phi_2-\cos\phi_1).$$

If the course makes an angle ϕ_3 with the datum after the second turn, ϕ_4 after the third turn and so on, the final position error resolved along the datum line is :

$$2R\sin\frac{\alpha}{2}(\cos\phi_2-\cos\phi_1+\cos\phi_3-\cos\phi_2-\ldots$$
$$+\cos\phi_n-\cos\phi_{n-1})$$
$$=0\text{ if }\phi_n=\phi_1\text{ and is an any case small.}$$

The errors resolved in a direction perpendicular to the datum cancel out in a similar way.

The errors due to over- or under-reading of the log during the turn do not cancel out. If the mean line of advance is taken as datum, the error resolved in a direction perpendicular to this line cancel out by symmetry, but the error resolved along the mean line depends on the distribution of courses around the mean line of advance. If all values of ϕ from $-\pi/2$ to $+\pi/2$ are equally frequent, the summation of errors amounts to about $0{\cdot}8\,N\left(\frac{V_L}{\Omega}-R\right)$ where V_L is the reading of the log, Ω the rate of turn, R the distance from the log to the instantaneous centre of rotation, and N the total number of turns. If the number of courses making angles to the mean line of advance which lie between ϕ and $\phi+\delta\phi$ is given by the expression $C\cos^2\phi\delta\phi$, the error is $0{\cdot}6N\left(\frac{V_L}{\Omega}-R\right)$ approximately.

The final plot error lies then along the mean line of advance. Its magnitude depends on the type of ship, speed, rate of turn and frequency of change of course. The figure given in the table is based on typical behaviour of a medium sized naval vessel fitted with a pitôt log making one turn per mile.

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Admiralty Navigation Manual.

"Ships' Speed Meters," H. Hoppe, *Trans. Inst. Engineers and Shipbuilders*, Vol. 81, Paper 988, April 12, 1938.

"The Measurement of Sea-Water Velocities by Electromagnetic Induction," R. W. Guelke and C. A. Schoute-Vanneck, *Journal I.E.E.*, Vol. 94, Part II, page 71, and Vol. 94, Part I, page 232, 1947.

Aeronautical Garden Party

On Sunday last, the Royal Aeronautical Society held its annual garden party at Wisley Aerodrome. A static display gave members and their guests the opportunity to refresh memories of Avro "504," Sopwith "Camel," "S.E.5," and Fokker "D.7," as well as earlier and lesser-known aircraft in the Nash collection. The flying programme, carried out in completely still air, was also performed largely by aeroplanes of historic interest, ranging from the Hawker "Cygnet" light biplane with its 35 h.p. Bristol "Cherub" twin to a Fairey "Swordfish," notably nimble with no war load, and from a tiny Mikron-engined "Tipsy" to "The Last of the Many," the "Hurricane" sharing its display with a "Spitfire" in service colours. Specialised crop-dusting aeroplanes were able to show off their low speeds and tight manœuvres, while a parked aircraft carried a set of rotating dispensers, driven by windmills, for pest control work. A formation of four Miles "Magisters" showed just how low flying could be, and a graceful Beech "Branza," (its clean and simple lines emphasised a restrained finish in two colours) exemplified the private aircraft of the second post-war period.

American and other Contributions to Engineering History

(Contributed)

IT is the role of technical literature not only to describe what has actually been accomplished in the field of technology, but to concentrate as much light as possible on those developments which may be taking shape beyond the horizon of practice. The shelves of our science libraries bend under the ever-increasing weight of historical literature, much of it valuable, and we may be excused for preferring, among the historical books, those which most stimulate our imagination. Contemplating such a compilation as the *Chinese Encyclopædia* of 1726 with its 5020 volumes, we may (like Ingres) lift our hats, but we shall be likely—as he did—to look the other way. Justly prominent in the literature of science is that *Encyclopédie ou Dictionnaire Raisonné des Sciences, des Arts et Métiers*, which, designed and edited by Diderot (in conjunction with D'Alembert) was intended to explain "the observed results of every science and the mechanical processes of every trade." Publication commenced in 1751 and was not completed until 1765, when there appeared the seventeenth folio volume, and eleven volumes of plates. Diderot's labour on this *Encyclopédie* was prodigious, his hunger for accuracy taking him into workshops and factories that he might try "his own hand at the loom." In the end he became so impoverished that but for the generosity of Catherine the Great, he would have been obliged to sell his library. Two centuries have passed since Diderot was active and at the time of the publication of the *Encyclopédie* industry as we know it to-day did not exist.

The above observations are suggested to the writer by perusal of a book entitled *Engineering in History*,* the authors being Richard Shelton Kirby, Sidney Withington, Arthur Burr Darling and Frederick Gridley Kilgour. This well-informed team of American technicians and teachers has set out to compose "A pictorial account of the development of engineering in Western civilisation from its origins down to our twentieth century with interesting highlights on its contributions to human society." Realising the range suggested by the title, the authors tell us, in the preface, that the volume is intended to give "both student and general reader a knowledge and understanding of engineering history." It is certainly a courageous plan to attempt, in 530 pages, 9in by 6in, to cover so tremendous a field and to cope with the constantly recurring problem of selecting, from the mass of material available in every category, the item or items deemed to be of predominant importance. Many years ago Louis Agassiz, then a professor at Harvard, was asked to deliver—before an artisan's school at Boston—a lecture on fishes. He declared it to be a thing impossible; he could not give a lecture on fishes, but he would be only too pleased to give "a course of lectures on a fish scale." The authors of the present book may have had the same feeling when planning their admirable work.

It would be generally allowed that the years between 1765–1785 witnessed the beginning of the modern industrial world. In 1769 not only had Watt patented the separate condenser, but Arkwright, six months later, had patented his spinning frame. The collective effect of these two inventions was to prove revolutionary, the utility and productivity of Arkwright's machine being multiplied out of all proportion by the application of steam power. The potentiality of this combined development was but dimly recognised at the time, though during 1786 there arrived in England a visitor from America, who, after viewing the Watt rotative steam engine, clearly foresaw the vast industrial and social changes which lay just over the horizon. This visitor was Thomas Jefferson, author of the Declaration of Independence, who had examined, among other things in Great Britain, the rotative steam engines at Albion Mill, Southwark. It is not sufficiently realised that the history of the engineering industry was appreciably influenced by the prescience and activity of such as Benjamin Franklin and Thomas Jefferson, and by the encouragement given by George Washington to the marine propulsion labours of James Rumsey. It cannot be said that the authors have in any way exaggerated the accomplishments of American engineers, indeed, among the admirable features of this book is the clarity with which engineering is set forth as an international activity wherein all nations participate and to which citizens of all nations have made momentous contributions.

It is to be noted that apart from giving details of structures, equipment and methods, the authors also describe early efforts directed to the amelioration of working conditions—a subject in which Americans have always shown interest—particularly interesting being the reference to the writings (mid-sixteenth century) of Vannoccio Biringuccio. It is salutary to be reminded—as we are by this book—of the fact that inventive activity did not commence with the passage of the Statute of Monopolies, nor humanitarian activity with the social legislation of the past century.

A reference in this book to Frederick Winslow Taylor makes it seem strange to the writer that so little has been said about those American engineers whose names are indissolubly connected with the development of mass production and of the tools required in giving effect to it. We do not, for example, find in this book any reference to such as Eli Whitney, Simeon North or Elisha King Root, nor much elsewhere. Yet the influence of their labours—together with those of Whitworth and others—have proved momentous for us and for posterity. To-day, while scientific management has made, and is making, great progress, we are still a long way from arriving at industrial harmony. This is what Taylor had in mind when he announced the two conditions without which scientific management cannot be said to exist. The second of these conditions was that special attention must be given to "the accurate study of the motives which influence men." Taylor himself, unflagging and revolutionary as were his efforts to promote efficiency and eliminate waste never—so far as we know—had a strike in any of the works which he managed. Very significant, it seems to the writer, is the fact that in an article written by Lenin, and printed in *Pravda*, April 28, 1918, there occur the words: "We must introduce in Russia the study and teaching of the new Taylor System." Taylor was not only a pattern-maker and a machinist (in which trades he served his apprenticeship), but he joined the Midvale Steel Company as a common labourer. In the course of his life, first as a workman and later as an executive, he had reached the conclusion that antagonism between employer and employee could only be abolished by knowledge—based on accurate data—of facts. These facts he collected and made available. No matter how impressive the façade of facts, there remain for solution psychological as well as technological problems which call for the exercise of humanistic as well as managerial functions. The extension and intensification of routine operations in engineering industry is not confined to the workman, a circumstance recognised more than a century ago by Auguste Comte. "If" (he remarks), "we have been accustomed to deplore the spectacle, among the artisan class, of a workman occupied during his whole life in nothing but making knife handles or pin-heads, we may find something quite as lamentable in the intellectual class, in the exclusive employment of the human brain in resolving equations or classifying insects. The moral effect is unhappily analogous in both cases. It occasions a miserable indifference about the general course of human affairs so long as there are equations to resolve or pins to manufacture." Certainly the moral effects mentioned by Comte are among the problems remaining with us, but we can at least remember and act upon some words uttered not long since by an American industrialist of great experience: "What we need to deal with," he said, "are not the limits to which men may go without physical exhaustion, but the limits within which they may work with zest and spirit and pride of accomplishment." It is not, of course, the manual worker alone upon whom we depend. Indeed, there is a marked tendency to overlook the weariness of the non-manual worker; of him who belongs to what Comte calls the "intellectual" class. We shall therefore conclude with quoting a helpful hint from an eminent mathematician who has been mentioned at least twice in the book now before us: William Oughtred, well remembered not only as the inventor of the slide-rule, but as an esteemed friend of both Sir Isaac Newton and Sir Christopher Wren, left on record the prescription used by himself for the relief of tedium: "As oft," he writes, "as I was toiled with the labours of my own profession, I have allayed that tediousness by walking in the pleasant and more than Elysian fields of the diverse and various parts of human learning and not of the mathematics only."

* McGraw-Hill Book Company Inc., New York.

Institution of Electrical Engineers

THE Institution of Electrical Engineers has announced that the president of its council for the next session will be Sir Gordon Radley, K.C.B., C.B.E., Ph.D.(Eng.). The two vacancies for vice-presidents will be filled by Mr. S. E. Goodall and Mr. S. C. Lucas, and the honorary treasurer will be the Rt. Hon. The Viscount Falmouth. There were six vacancies for ordinary members of council and they will be filled by Messrs. J. A. Broughall, B. Donkin, A. H. Mumford, D. P. Sayers, H. Watson Jones, and H. West. The one vacancy for an associate member will be filled by Mr. E. M. Hicken. The chairmen of the specialised sections will be: Measurement and Control Section, Dr. D. Taylor; Radio and Telecommunication Section, Dr. R. C. G. Williams; Supply Section, Mr. P. J. Ryle; Utilisation Section, Mr. H. J. Gibson.

LETTERS AND LITERATURE

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondtns)

WHYMPER AND THE MONT CENIS TUNNEL

SIR,—I was disappointed when I saw the first of the "Engravings of 1871," on page 22 of the current issue of THE ENGINEER, to find no mention of the engraver, Edward Whymper. From the quotation in the caption it is apparent that the original article was based almost verbatim on the description given in Chapter III of *Scrambles Amongst the Alps*, which appeared that year. The author is, of course, well known for his pioneer mountaineering exploits described in this classic work, but recent editions of the book omit completely the chapter on the Mont Cenis Pass and the then recently completed railway tunnel. The original article you published no doubt gave all the customary statistics as to the size of the tunnel, its temperature, &c., but the further comparisons made by the author on the application of mechanical aids to coal mining have a surprisingly modern ring. These perhaps may be of interest to your readers.

After comparing the "old, barbarous, wasteful methods still employed" with the "mechanical power, skillfully applied," and taking the pit-owners to task for their indifference to the loss of 200 lives every year by firedamp explosions, he points out "that the time is rapidly approaching when they will be unable to compete with foreign markets, unless they work with greater economy."

Whymper goes on to point out that the fire hazard from smoking, matches, &c., cannot be combated by "repressive enactments," but by eliminating the cause of explosions through better ventilation. To kill two birds with one stone, his solution is the use of coal cutting machinery operated by compressed air, and the invention of such a machine in 1861 is noted. This is claimed to have been working successfully at the West Ardsley pit in Yorkshire, and it was asserted that there had been "only a single explosion since the machine has been in use, although there were many minor ones before it was introduced." The chapter closes with the suggestion that the man who improves the ventilation of the mines will be a greater benefactor to his country than Sir Humphrey Davy!

T. L. WATKINS

London, E.C.1,
July 12th.

[We are obliged to Mr. Watkins for pointing out that Edward Whymper was the engraver of the illustration and for reminding us of Whymper's apt comments on mining methods. —ED., THE E.]

LOADING IN BRACKET BOLTING

SIR,—In estimating the tensile loading in the bolts attaching a bracket of the type in Fig. 1 to its support, a common method is to assume tilting to occur about an axis *A* near to the lowest bolt, the bolt loading being taken as increasing linearly from zero at *A*. The resulting internal moment of resistance is then given by :

$$P_1 \cdot \frac{\Sigma x^2}{x_1} \quad . \quad . \quad . \quad (1)$$

where P_1 is the load in the extreme bolt at x_1. This method ignores the important effect of the initial tightening of the bolts; assumes a base reaction concentrated near the lower edge; and by over-estimating the leverage, under-estimates the bolt loading.

The actual conditions may be more generally stated. When the bolts are initially (and equally) tightened during assembly, a pressure is set up between the bracket base and support faces, the resultant of this contact pressure coinciding with that of the bolt loads. Under load the contact pressure distribution alters, displacing the resultant *R*, and the bolts may undergo some varying increment of load. The conditions are as represented in Fig. 2, where

ΣP = total initial bolt load (acting at centroid of group).
Σp = total increment bolt load.
R = resultant of contact pressure force.

The internal moment of resistance, about an axis at *R*, becomes :

$$y\Sigma P + y^1\Sigma p \quad . \quad . \quad . \quad . \quad . \quad (2)$$

The use of this equation requires the determination of the position of the resultant *R*, and consideration of the induced increment tensions *p*.

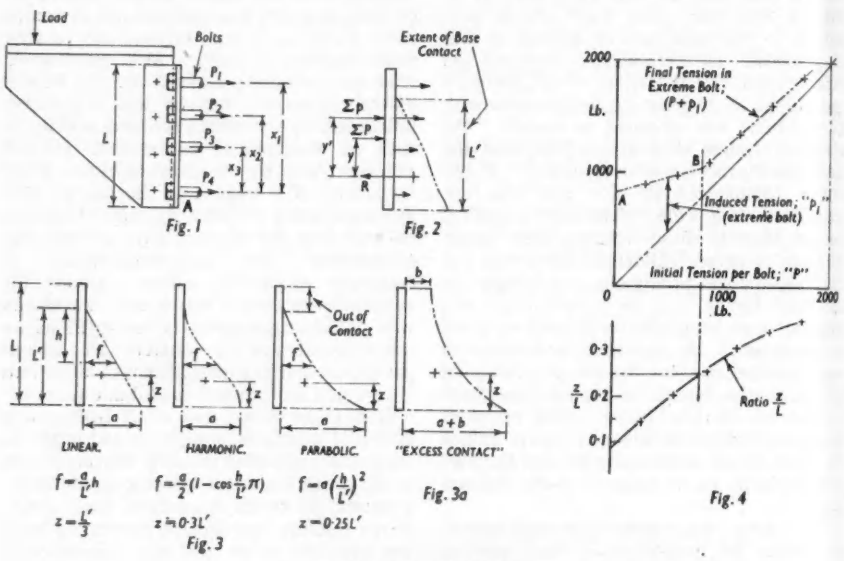
Some minimum value of initial bolt tension will be necessary to ensure contact over the full extent of the base, when the bracket is externally loaded. With smaller values, contact will only be "partial," allowing some part of the base to break away from the support face—with consequent effect on induced increment bolt loading. The conditions are determined by the nature of contact pressure distribution. Tentative suggestions for this (within partial contact range) are indicated in Fig. 3—the intensity across width being assumed constant at any point—although the actual form is not likely to be of such simplified nature. The significance is in the position of *R*, distant *z* from "heel" edge. When the bolt preloading exceeds that required just to give full base contact ($L^1 = L$), a further increase *b* in the contact pressure occurs over the base depth *L*, as at Fig. 3*a*. At this point, therefore, a change in the rate of variation of *z*, in relation to degree of initial loading, may be expected, and also a change in the proportion of induced increment loading.

This note has been prompted by the writer's examination of the results of some tests, reported by Marshall and Hoo,* on the bracket of Fig. 1. The bolt loads were measured before and after application of the bracket loading. Fig. 4 has been deduced from these results, the ratio z/L being determined from equation (2). Point *A* corresponds to the conditions of equation (1), and it will be seen that this gives a minimum bolt load. A significant change in the variation of induced loading occurs at point *B*—a point to which the original authors make only passing reference. It may be inferred that this represents the condition for which the full extent of base contact, under loaded conditions, is just attained—initial bolt tensions below this value allowing the bracket and support faces to partially separate. It will also be noted that *B* corresponds to a z/L value of about 0·25, indicating that the contact pressure distribution approximates to the parabolic nature of Fig. 3.

The variation of induced tensions in the bolts may be taken as roughly proportional to distance *x* from an axis near to the heel. If $p_1 = kP$ is the value at the extreme bolt at x_1, the moment contributed by the induced tensions is :

$$kP\frac{\Sigma x^2}{x_1}$$

—the second term in equation (2). The values



Loading in Bracket Bolting

* "An Experimental Investigation of the Stresses in Angle Brackets."—*Proc. Inst. C.E.*, Dec., 1951.

of k may be inferred from Fig. 4, becoming progressively smaller as initial tension value is increased. A close enough approximation is obtained by including p with P, to give the simple expression :

$$\text{Moment of resistance} = ynP_1 \quad . \quad . \quad . \quad (3)$$

where

P_1 = final tension in outer bolt (a portion of which is induced).
n = number of bolts.

In evaluating y—the distance of the centroid of the bolt areas from R—the minimum value of z/L to give full extent of base contact is about 0·25. Under this condition, the required initial tension will be about 80 per cent of P_1 (from Fig. 4). If this preloading be exceeded, the final tension reached will also increase, but by a decreasing proportion.

Hence the method here suggested for the design of such bolting, for a bracket of the type considered, is to take z/L as 0·25, and with y determined for a given bolt layout, to calculate P_1 from equation (3). Little experimental data appears to be available relating to this matter, and for other bracket forms than that dealt with. The present note may facilitate such testing.

J. E. KEOWN

The University, Glasgow,
June 18th.

EFFECT OF DISTORTION OF A STIFF-JOINTED FRAME ON ITS PLASTIC COLLAPSE LOAD

SIR,—In their reply (in your issue of July 6th) to my earlier letter, Professor King and Mr. Jenkins fail to appreciate my main criticisms. The point which I was endeavouring to make in my diagram was that the deterioration of frame stability due to the formation of some plastic hinges may lead to overall instability before all the hinges requisite for a mechanism have been formed.

The authors, by assuming the moment at the stanchion foot to be $Mp/2$ at point G in Fig. 3 of their paper, are merely calculating a point on the load-deflection curve for their structure. The load thus calculated is not the collapse load, and Figs. 3, 5 and 6 are incorrect in their interpretation of loads so derived.

Finally, with regard to the calculation of deflections, my criticism was that the authors had not outlined a generally valid method, and not that the procedure they mentioned was insufficiently accurate.

M. R. HORNE

University of Cambridge,
July 11th.

Literature

The Disposal of Sewage. Third edition. By T. H. P. VEAL. Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 30s.

THE first edition was addressed to students; and while this new edition is stated as being a textbook for the use of engineers, sanitary inspectors and students, the general character remains the same.

The text includes an introductory chapter that is entirely historical ; a chapter on the " Quantity of Sewage " dealing with estimation of flows of soil sewage, storm water and trade waste, and giving some information on storm overflow chambers ; and another on " Analyses of Sewage and Their Meaning." Dealing next with the processes of treatment, Chapter IV covers screening and detritus settlement, also storm water tanks. Chapter V describes processes of primary sedimentation and Chapter VI treatment by percolating filters. Chapter VII is entitled " Bio-aeration Tanks," but in fact covers most methods of activated sludge treatment, including the diffused air process, Simplex process, Kessener process and bio-aeration method : it also refers to partial treatment, and compares activated sludge processes with other methods. This is followed by a chapter on the disposal of sludge, and another on treatment of trade waste, the latter being a new addition to the book. The tenth chapter is entitled " Layout and Construction of Sewage Disposal Works," but covers also brief reference to pumping, flow measurement, costs and trend of future development. The eleventh and final chapter, " Sewage Disposal in Rural Districts," is partly concerned with small village schemes and partly with cesspools and treatment works for isolated premises. There is an appendix outlining calculations for a sewage treatment scheme for a town of 50,000 inhabitants, and an index.

The general impression is that, from the student's point of view, the subject is fairly well covered and, in places, very well. But it is necessary to comment that considerably more work could have been done in the revision of the text. Certainly there are references to recent methods such as alternating double filtration, recirculation and enclosed filtration ; to the new Colne Valley works ; to dome diffusers, the experimental freezing of sludge, synthetic detergents, radioactive wastes and micro-straining. But these additions are like putting a piece of new cloth unto an old garment, for the greater part of the text appears as a fair description of the state of knowledge, practice and conditions prevailing in the early 1930s. There are, for example, references to the requirements of the Ministry of Health reminiscent of the belief in those fictitious " Ministry of Health Requirements " that was dispelled prior to the second world war. In some instances Ministry of Health is put where, one suspects, Royal Commission is meant. There is no mention of the Ministry now concerned—i.e. that of Housing and Local Government. Similarly, it is not only those processes that are included merely for historical interest that are obsolescent or obsolete. Further, the same impression as to date of the text is given by the statements that : " In a sewage analysis it is customary to express quantities of impurities present in parts per 100,000 (by weight), or in grains per gallon . . ."; and " Under favourable conditions the cost of sewage works may work out at less than £2 to £3 per head of population served. . . ." This latter quotation very much dates the work.

Report on the Multiple-Purpose Plan for Permanently Controlling the Yellow River and Exploiting its Water Resources. By TENG TSE-HUI. Britain-China Friendship Association, 228, Gray's Inn Road, London, W.C.1. Price 1s. 6d.

LAST July, approval was given by the Chinese Government to a vast plan for controlling the Yellow River. The plan was prepared with technical assistance from Russia, and involves a " ladder " of forty-six dams, hydro-electric power installations to the extent of 23,000MW capacity and 110,000 million kWh annual output, irrigated areas totalling 116,000,000 mou (1 mou =0·165 acres), and a navigable length of river of 3610 km. At present 16½ million mou are irrigated, and 160 km of the river is navigable. The largest dams of the scheme would form reservoirs of great size ; for instance, the Luichia gorge would be dammed at a site with a power potential of 1000MW. At the Sanmen gorge reservoir site 600,000 people would have to be resettled.

Although it gives the main statistics of the plan and emphasises the problems of flood protection and soil conservation, this booklet is primarily political, rather than technical. Its author is the Chinese vice-premier. He refers to the three American civil engineers—Messrs. Savage, Reybold and Growdon—who made a report on the Yellow River in 1946, in which they are quoted as saying that hundreds of years would be needed to treat the entire area. However, Mr. Teng Tse-Hui asserts that only a few decades will be needed to see results from water and soil conservation works in the Loess region ; and in six years, when the Sanmen Gorge reservoir is completed, he adds, the water in the lower reaches of the Yellow River will be practically clear. These aims are emphasised by patriotic exhortations to those concerned.

Modern Workshop Technology : Part I, Materials and Processes. Second edition, Edited by PROFESSOR H. WRIGHT BAKER. D.Sc., M.I.Mech.E. Cleaver - Hume Press, Ltd., 31, Wrights Lane, London, W.8. Price 35s.

THE revised and enlarged second edition of this book includes new sections on casting methods which have been developed extensively since publication of the previous edition in 1948, on high tensile steel wire manufacture, and on the production of bright steel bars. As before, this first part deals with the states and properties of the commoner engineering materials, and the second part will deal with the processing of materials.

Books Received

Fluid Flow in Practice. Edited by J. R. Caddell. Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 24s.

Differential Equations. By S. V. Fagg. The English Universities Press, Ltd., 102, Newgate Street, London, E.C.1. Price 7s. 6d.

Principles of Turbo-Machinery. By D. G. Shepherd. The Macmillan Company, New York. 10, South Audley Street, London, W.1. Price 56s.

The Running and Gating of Sand Castings. By R. W. Ruddle. The Institute of Metals, 4, Grosvenor Gardens, London, S.W.1. Price 25s.

Automatic Process Control for Chemical Engineers. By Norman H. Ceaglske. Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 54s.

Electronic Measurements and Measuring Instruments. By F. G. Spreadbury. Constable and Co., Ltd., 10, Orange Street, London, W.C.2. Price 50s.

Automatic Digital Calculators. Second edition. By A. D. Booth and K. H. V. Booth. Butterworth's Scientific Publications, 88, Kingsway, London, W.C.2. Price 32s.

Route Surveys and Construction. Third edition. By H. Rubey. The Macmillan Company, New York. 10, South Audley Street, London, W.1. Price 44s.

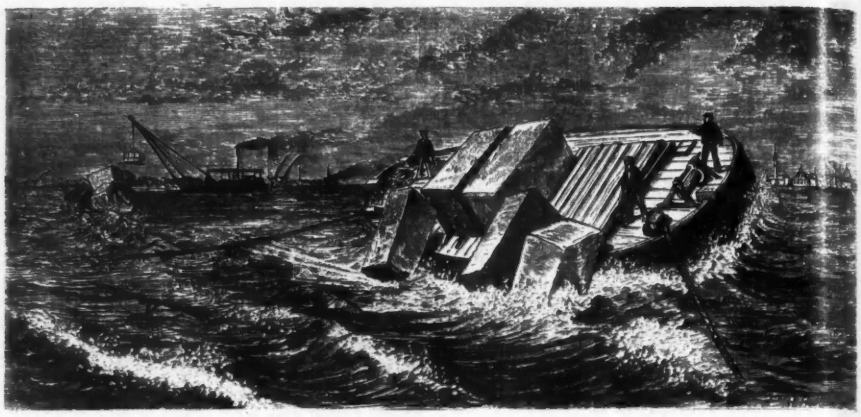
Reference Manual of German Machine Tools. English Edition. By Hermann P. Gentzel. Verlag Karl Ihl and Co., Coburg, Bavaria, Germany. Price 47s. 6d.

Definitions and Formulæ : Modern Physics. Third edition. By L. R. B. Elton. Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, London, W.C.2. Price 2s.

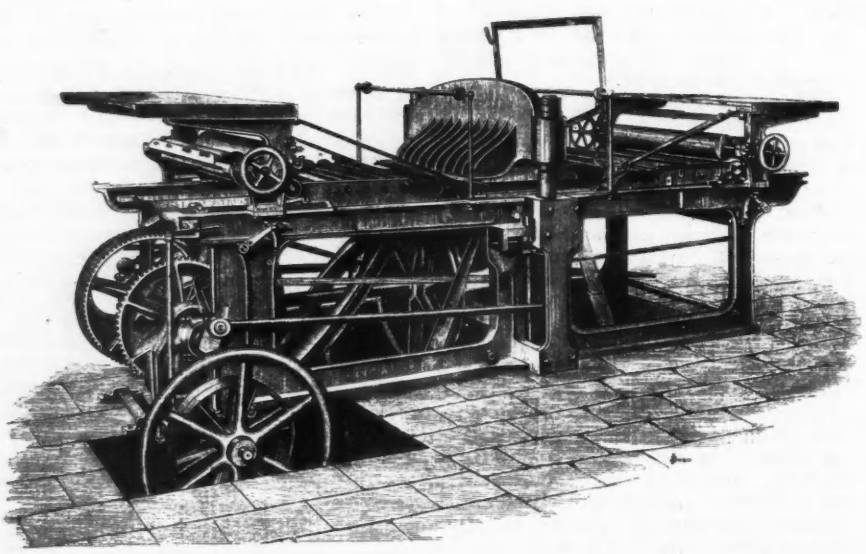
Electricity, Magnetism and Atomic Physics : Vol. I, Electricity and Magnetism. By J. H. Fewkes and J. Yarwood. University Tutorial Press, Ltd., Clifton House, Euston Road, London, N.W.1. Price 36s.

The Manufacture of Glycerol : Vol. III, The Modern Soap and Detergent Industry. Second edition. By H. J. Strausz. The Technical Press, Ltd., 1, Justice Walk, Lawrence Street, London, S.W.3. Price 84s.

ENGRAVINGS OF 1872

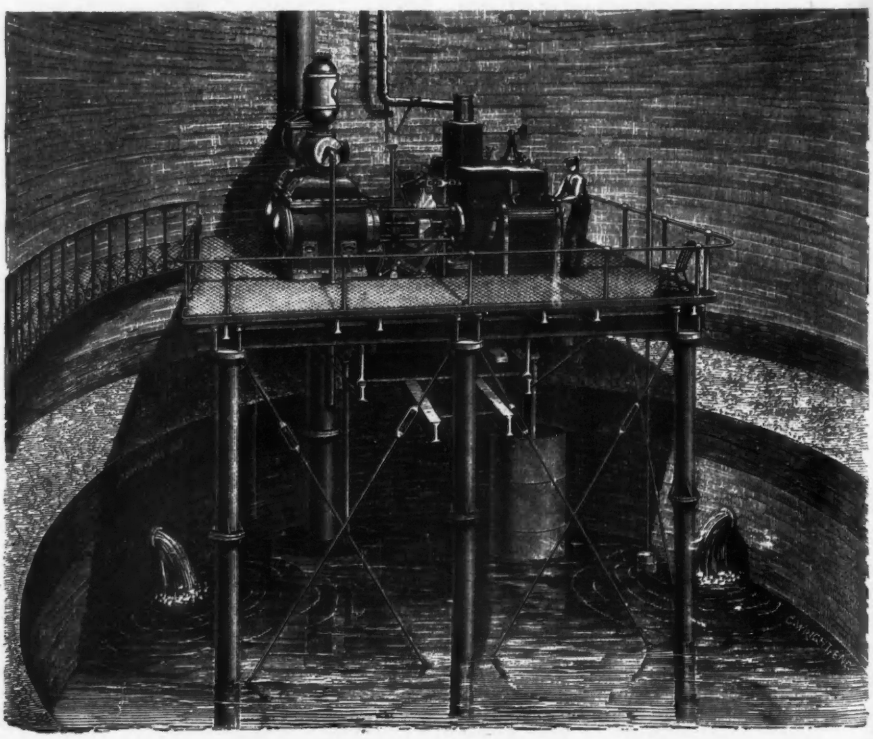


The right-hand engraving was first printed in our issue of December 13, 1872, under the title "Tipping Concrete Blocks, Alexandria Harbour." The works at Alexandria, which were started in 1869 by Greenfield and Co., consisted of "a breakwater about a mile and a half long, running in a pretty direct line from the lighthouse on Eurotus Point towards Mex." The breakwater, we explained, was "to be constructed after the plan of that at Port Said, by simply tipping into the sea immense blocks of concrete."



This engraving (left) illustrates Napier's platen printing machine, which was described in our issue of August 16, 1872. It was constructed "for the execution of work of the highest class." Our article says: "the machine is a double-feeder, with tympans and friskets of the usual form, with perfect arrangements for overlaying and registration, and while one tympan is under the platen a clean sheet of paper is being placed on the other. The platen is of great weight and solidity of construction, but additional force is given to it by a huge mass of metal suspended beneath, and which may be seen in the engraving, in which it appears like a huge beam crossing the frame of the machine and the well beneath; this supplementary load is about half a ton in weight. The platen is worked by means of knee joint levers on each side, worked by cranks and connecting rods."

In our issue of September 6, 1872, we included a description and some illustrations of the Great Well at Prospect Park, Brooklyn. The accompanying engraving shows the interior of the well. Our article explains that this particular view depicts the pump platform "but does not show a handsome winding staircase by which the platform is reached from the top." The well, which "was believed to be the largest in the world," was covered at the top, except for a central opening 20ft in diameter. The description goes on to say that "this opening is surrounded by an ornamental iron railing. The annular covering outside the railing is of timber. The diameter of the well immediately underneath this platform is 45ft. The diameter then gradually increases till the well reaches a depth of 53ft below the timbers of the platform, at which point the diameter is 50ft. The diameter is then abruptly decreased to 35ft, leaving a level shoulder, and forming, so to speak, a second shaft, which descends 11ft or 12ft deeper, and which also has a slight increase of diameter toward the bottom." It is then explained that "the engine is of the kind known as the Worthington duplex pumping engine, consisting essentially of two direct-acting horizontal engines, by the side of each other. The capacity of the engine is such that it will easily deliver into the reservoir one million gallons in twenty-four hours, through 465ft of 12in pipe, at a height of 160ft."



One Hundred Years' Omnibus Operation

On Monday last, the London Transport Executive staged a parade in Regent's Park to celebrate the Centenary of the London General Omnibus Company. The vehicles which took part, some of which are illustrated here, can be inspected on the Horse Guards Parade tomorrow.

IN 1856 the Compagnie Generale des Omnibus de Londres began services with a fleet of horse buses purchased from the manifold previous operators. The bus of that period was not generally accepted as satisfactory, and our own views, expressed later that year, were as follows :

" If you want a familiar sample of our fine old institutions, dear to routine, stolidity, and stagnation, take a London omnibus, with its precipitous entrance, its straw-littered floor, its fuzzy padding, its unkind interior, destitute of handrails or pillars in aid of desperate passengers, its procrustian capacity, and its stifling atmosphere or killing ventilation. To begin with the capacity, impenetrable builders insist that in London streets larger omnibuses could not be tolerated, as if we, the omnibus public, did not perfectly well know that great lumbering waggons, double the capacity of an omnibus, did every day traverse our streets, not, certainly, without causing interruption, but at least compatibly enough with the other traffic. We have been at pains to measure the interior of some of our omnibuses, and find that they measure from 8ft 4in to 8ft 9in in length, along the seat, which allows from 16½in to 17½in for each passenger, six in the row. . . The situation destroys the dress and hurts the feeling ; for who can, without an effort of self-control, resign himself to the close embraces of un-guaranteed and sometimes improbable strangers on either side ?

"Next as to the width . . . In reality, the omnibuses measure from 4ft 2in to 4ft 4in inside width, and hence it is bruising work for passengers' dresses, not to mention the leather-clad extremities. When passengers move into or out of the vehicle, there is invariably a scuffle of patellas ; in fact, there is not room for two legs ' abreast ' between the knees of the opposite sitters. Knowing passengers make their way to the door by keeping one foot foremost in single file, an addition to the width is, perhaps, a more important consideration than increase of length, taken externally ; but there seems little difficulty in devising an extra width of 3in or 4in on each side, by only reducing the 5in or 6in clearance that now exists between the wheels and the body on each side, the wheels remaining at the same gauge.

" The height from the pavement to the door-sill is about 2ft 6in, and how many steps do you suppose there are to get up ? One only.

" It is easier to ventilate a church than an omnibus . . . In carrying out any plan for ventilation, the first rule for direction would be to conduct the process of ventilation entirely above the level of the heads of passengers—that is, to prevent injurious drafts ; secondly, to constitute the plan of ventilation self-acting—that is, to place it beyond the control of individuals . . . Stinted half measures won't do, and colds need not be apprehended from overhead ventilation, for everybody wears his hat in an omnibus. Ladies, of course, are accustomed to drafts about the head, their bonnets being carried on their shoulders."

Nor did improvements come rapidly. The L.G.O.C. competition for an improved design drew many entries, a number of which we have described, but none were adopted by the Company. The major change that took place in the horse bus was the substitution of " garden seats " for the " knifeboard " provided for outside passengers. Since, with the *dos-a-dos* seating, the passengers had been bound to sit near the middle of the vehicle, whereas the new design opened the possibility of their all sitting at one side, we were not then in favour of seats across the vehicle, for in 1886 we wrote :

" We now and then find an omnibus with all its passengers outside. The centre of gravity is then dangerously high, and an accident may readily happen in a street rather more curved than usual, or by a wheel getting into a rut, or on to a gully-trap grate. As to the consequence which may ensue if an axle breaks, the less said the better. The fore-wheel of an omnibus broke the other day in the Old Kent road, with the result that the omnibus was upset, and that some thirty passengers were more or less hurt . . . It ought to be possible to build an omnibus with a maximum of comfort and safety, but it does not seem that it is. Impunity renders builders audacious."

A year later, in 1887, gas lighting was in use in omnibuses, and in 1892 we welcomed a trial installation of electric light :

" We trust that omnibus lighting by electricity will be largely used, as it is quite impossible with the present system of illumination to read inside most omnibuses at night."

Even before this time steam omnibuses and steam vehicles for " omnibus trains," some of which could turn off their rails when desired, had been in use. It was not, however, until 1904 that we greeted the London Power Omnibus Company :

" A start is being made with a service of motor omnibuses for London. . . . The omnibuses will carry fourteen passengers."

In the same year, the General initiated services with mechanically propelled vehicles, using the Clarkson steam bus illustrated. Unlike the Clarkson, the majority of the steam omnibuses were based closely upon horse bus practice, and in some cases the chassis was designed to carry a horse bus body. In all cases the engineers put their motive power where the horses had been, at the front, and in one case followed to the logical conclusion by driving the front wheels. This vehicle had a complete steam power plant mounted on the forecarriage of a horse bus, the driver sitting in the existing seat with the steering column running down between his legs.

The bulk of the early horse-less buses were imported, and in many cases it was found that the vehicles were unsatisfactory in service, at least in London. The police insisted vigorously on standards of construction and maintenance, including such matters as oil leaks, and forced many of the vehicles to be discarded. The " General " ordered fifty Bussing chassis from Straker and Squire in 1905, and instructed the coach factory " not to put any more work in hand in connection with horse buses."

" B," " K," " S," and " NS " buses outside the Chiswick works in 1923 : the works overhauled only these vehicles, all of which were made by the A.E.C. All but the " S " took part in the parade

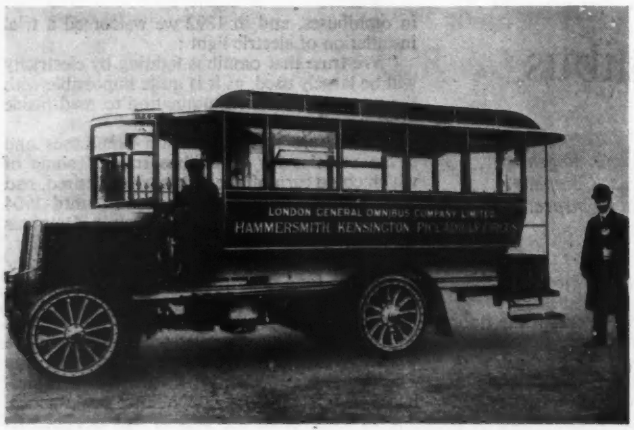
In January, 1906, we recorded :

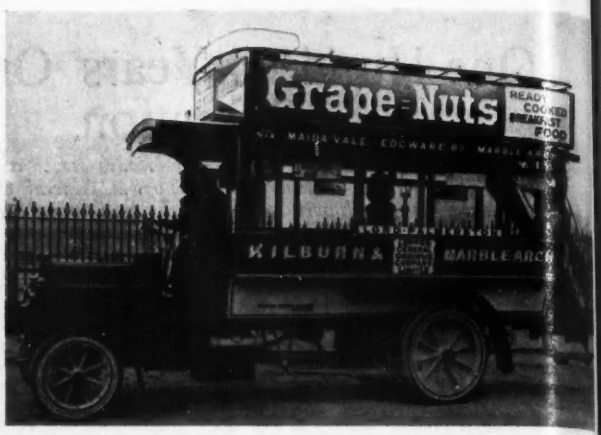
" Twelve months ago the number of motor omnibuses running in London was twenty. It has now risen to 230, and great increases will shortly be effected."

However, the transition did not take place entirely without incident, for on June 6, 1906, we were impelled to comment :

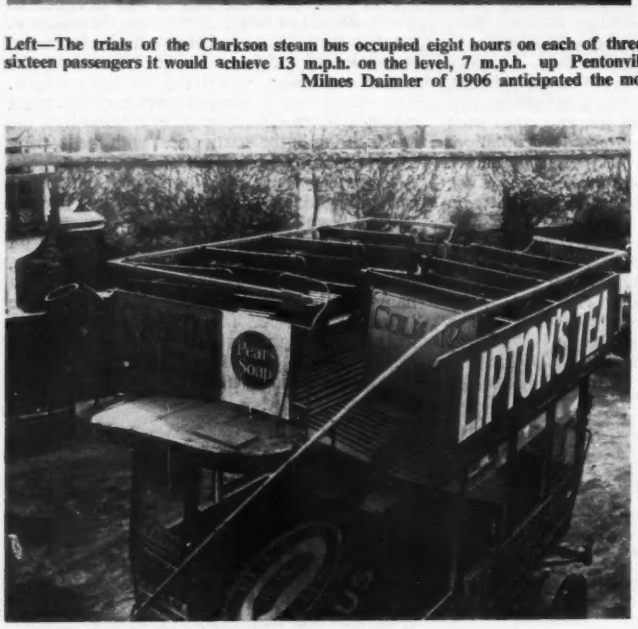
" Within the past week two cases of broken steering gears have occurred on motor omnibuses in London. Accidents of this kind should be made practically impossible, as the consequences of such defects are likely to have a deterrent effect upon the public."

A bus used in numbers by the " General " at this time was the Milnes Daimler, one of which we illustrate. The company, after purchasing many different motor buses, made a few designs of its own, and then launched the historic " B " type. The last " General " horse bus was run in 1911, and in the following year the Associated





Left—The trials of the Clarkson steam bus occupied eight hours on each of three days, and it exceeded the maker's guarantee that with a load equivalent to that of sixteen passengers it would achieve 13 m.p.h. on the level, 7 m.p.h. up Pentonville Hill, and consume less than a gallon of paraffin for 3 miles. Right—The Milnes Daimler of 1906 anticipated the modern "Routemaster" in its rear suspension



Left—"Garden seats" outside a horse bus. On the left can be seen a "General" "B" type bus. Right—"Ole Bill," which was lent for the parade by the Auxiliary Omnibus Companies' Association, is seen here in service after the war. Behind it can be seen a "K" type; with forward control and a straight-sided body with wheel arches, it carried twelve passengers more than the "B"

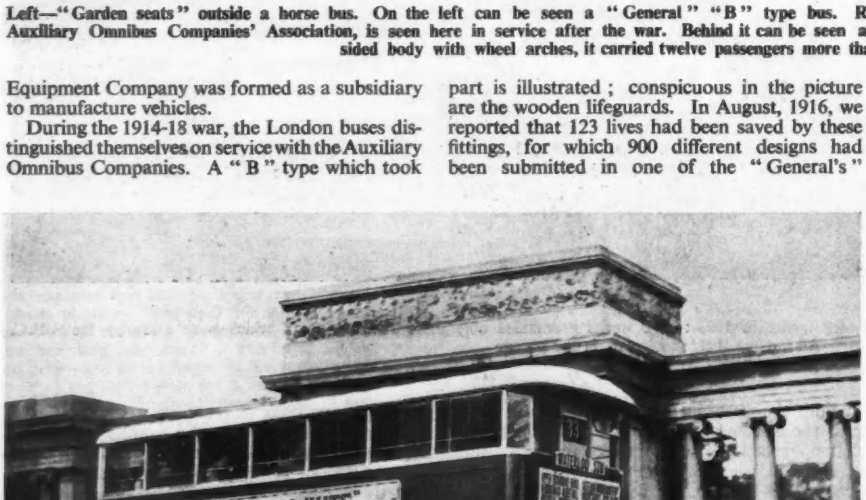
Equipment Company was formed as a subsidiary to manufacture vehicles.

During the 1914-18 war, the London buses distinguished themselves on service with the Auxiliary Omnibus Companies. A "B" type which took part is illustrated; conspicuous in the picture are the wooden lifeguards. In August, 1916, we reported that 123 lives had been saved by these fittings, for which 900 different designs had been submitted in one of the "General's" competitions.

Immediately after the war the "K" type was introduced. It accommodated cross seats on the lower deck by using arches over the rear wheels. The question of stability was again raised, and after an accident at Shooter's Hill we discussed the matter at some length, concluding that the contemporary double-deckers were adequately stable.

In 1922 we described the works established by the L.G.O.C. at Chiswick to overhaul its "B," "K," "S," and, from 1923, "N.S." buses, all built by A.E.C. The "N.S." was originally designed with the upper deck enclosed, but not until 1925 was the covered version approved for service.

A fresh line of development was started by the introduction of six-wheeled chassis, the first of which was the "London Six" illustrated. Once the Metropolitan Police accepted the maximum width of 7ft 6in common to other parts of the country, the L.T. six-wheeler went into service, followed by the two-axle "ST" and "S.T.L." The latter, first used in 1932 and prominent until after the last war, brought the diesel engine, the epicyclic transmission and the fluid flywheel to London. More and more, however, it has become clear that the manual, or rather pedal, operated preselector survived on the capital of judgment inculcated by the earlier "crash" boxes, and the latest "Routemaster" has a similar self-changing gearbox which follows the selector lever immediately and automatically.



The "London Six" of 1927 was designed to replace tramcars and carried sixty-eight passengers

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SINGLE-SPOOL TURBO-PROP.—The Napier "Eland" N.El. 1 has passed a 150 type test at a rating of 3060 equivalent horsepower. This engine features single-lever control by a hydro-mechanical system interconnecting fuel supply and airscrew pitch.

Explosives Manufacturing Plant at Ardeer

The Ardeer factory of the Nobel Division of Imperial Chemical Industries, Ltd., first started to manufacture nitro-glycerine in 1873. Since then this material has been produced by the batch process and later by the Schmid continuous system, and now by the Biazzi process, which continues the improvement in manufacturing technique and safety.

At the invitation of Imperial Chemical Industries, Ltd., we were able to visit the Ardeer factory of the Nobel Division of the company, the main object of the visit being to see that part of the plant engaged in the manufacture of nitro-glycerine.

The present factory at Ardeer, which consists of seven manufacturing departments and a maintenance section, covers about 2000 acres and employs a total labour force of approximately 7000 and provides excellent facilities for its workers, including canteens and a recreation club. Health services are well organised, there being, in addition to the first-aid room, a dental surgery and a physiotherapy department manned by nurses, two dental surgeons, two physiotherapists and administered by a medical officer. There are also a laundry, serving room, cobbler's shop and changing rooms. This overall outline of present conditions are a measure of the progress made since Alfred Nobel selected the site in 1871, when the factory occupied 100 acres and the staff and workmen numbered about 100.

It was in 1873 that nitro-glycerine was first made at Ardeer, although this discovery of Sobrero, made in Italy in 1845, had been manufactured on a commercial scale in 1862 at Heleneborg, near Stockholm, in a small plant started by Emanuel Nobel and his son Alfred. A disastrous explosion destroyed the plant in 1864, but Alfred Nobel continued with his experiments to manufacture nitro-glycerine safely, and in 1866 the first factory was built on the Continent, to be followed by many others in Europe and America. Their commercial success was assured by Nobel's discovery that twenty-five parts of kieselguhr would absorb seventy-five parts of nitro-glycerine to form a paste, which was given the name of dynamite, and by the invention of mercury fulminate cap.

The sensitivity of nitro-gylcerine to detonation by friction and impact, and the possibility of burning to detonation by ignition induced by its autocatalytic chemical decomposition in contact with mineral acids, have always made its manufacture hazardous. An additional care has been the need for control of the composition of waste acid, since acid mixtures can undergo vigorous oxidising reactions. Early manufacturing methods consisted of slowly adding glycerine to an open earthenware jug containing mixed sulphuric and nitric acids and stirring with a glass rod, the mixture being allowed to cool between additions of glycerine, since there were no means of removing the heat of reaction. However, within a few years air-agitated lead nitrators fitted with cooling coils and capable of producing 2000 lb of nitro-glycerine per nitration were in operation. The next improvement in manufacture to appear was the nitrator-separator and in 1908 the yield was raised from 85 to 95 per cent by the replacement of dilute acids by anhydrous mixed acids.

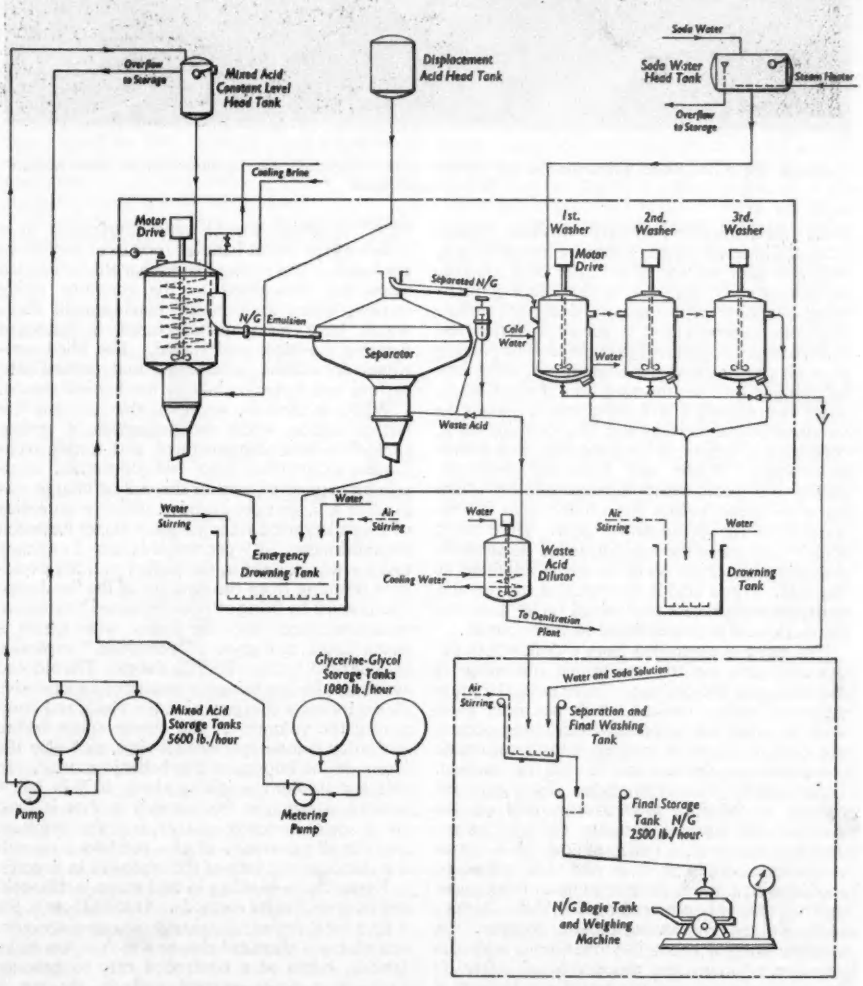
A continuous nitro-glycerine process was patented in 1927 by Dr. Schmid, of Vienna, and this method of manufacture superseded the batch nitration process in many countries. The advantages claimed over the latter process were reduced quantity of nitro-glycerine in the process, less labour, and greater compactness of plant. The first of such plants was installed at Ardeer in 1937 and had an output of 2500 lb per hour. Shortly before the war another method of continuous manufacture was put forward by Dr. Biazzi, the plant consisting of a nitrator, a separator and mechanically stirred washers fabricated in stainless steel. The design is more compact than the Schmid plant and its operation permits a further reduction in the quantity of nitro-glycerine in process. A Biazzi unit, with an output of 2500 lb per hour, is now in operation at Ardeer.

Batch, Schmid and Biazzi Processes

At Ardeer the batch process consists of an air-agitated nitrator, fitted with internal cooling coils, containing a mixed acid composed of 45 per cent nitric and 55 per cent sulphuric acids to which glycerine is added under manual control in quantities such that the reaction tempertaure is held between 15 deg. to 20 deg. Cent. A calcium chloride solution at −15 deg. Cent. is circulated through the cooling coils. The nitro-glycerine emulsion passes to a separator house, where the nitro-glycerine is skimmed off, and a second skimming taken before the waste acid is drawn off to the acid dilutor and de-nitration. A small amount of acid is left to ensure that no nitro-glycerine enters the system. The nitro-glycerine passes to a wash tank which is air agitated and supplied with cold water, and then on to a final wash-tank containing a 10 per cent solution of sodium carbonate. Here the nitro-glycerine is skimmed off by circular scoops having a pipe attached through which the nitro-glycerine drains off to a weigh tank. Small quantities of ortho nitro-toluene are added as a de-sensitiser before loading into copper containers having tinned interior surfaces. There is an emergency drowning tank connected to both the nitrator and separator.

In the Schmid continuous process glycerine and mixed acid are added simultaneously to a cooled nitrator, followed by the separation of the crude nitro-gylcerine in a static separator, from which the nitro-gylcerine overflows from the top and the waste acid is drawn off at the bottom. Stabilising of the acidic nitro-glycerine is by washing, in columns, first, with water, and, secondly, with a weak solution of sodium carbonate and then the final emulsion passes to a separator in the storage house. In this system all the reactants are fed to the various vessels under an air pressure of about 30 lb per square inch gauge, and automatic safety devices provide for the dumping, into a drowning tank, of the contents of the nitrator and separator should there be a temperature rise beyond the safety limit. Additional safeguards provide for the safety of the plant and personnel in the event of other eventualities occurring which are liable to set up dangerous conditions.

The stages in the Biazzi continuous process for the manufacture of nitro-glycerine are shown in our flow chart reproduced herewith. This 2500 lb per hour plant, of which we reproduce a photograph, has a nitrator, of about 50 gallons capacity, which has a spiral system of cooling coils through which sodium nitrate brine is circulated, entering at −5 deg. Cent. and leaving at +11 deg. Cent., at a rate sufficient to maintain the temperature of reaction between 10 deg. to 15 deg. Cent. Mixed acid in the proportion of 52·5 per cent sulphuric acid to 47·5 per cent nitric acid enter the nitrator through a constant level header tank and a metering pump supplies glycerine-glycol. Agitation is by a turbine wheel, motor driven at 750 r.p.m., which circulates the emulsion over the cooling coils before it passes through an overflow to the 200-gallon separator. The emulsion enters tangentially



Biazzi's continuous process for nitro-glycerine manufacture

so that it has a rotary motion which materially helps to separate the nitro-glycerine, which rises, while the spent acid leaves at the bottom of the vessel. Should the temperature rise in the nitrator or any other emergency arise, the contents of both vessels are dumped in a drowning tank which is fitted with water stirring and air stirring devices. Actually, free nitro-glycerine only occurs in the separator and according to estimates only about 125 lb is free out of the 1350 lb in the nitrating room, the remainder being in a safe emulsified condition.

The separated acidic nitro-glycerine flows continuously from the separator to the first of three mechanically agitated washing tanks, arranged in series, where it forms a fine emulsion, with an equal volume of a 12 per cent solution of sodium carbonate, due to the effect of high-speed agitators and specially designed baffles. Complete neutralisation is achieved during the time the two solutions are in contact while passing through the washers, the contents of which can be dumped into a drowning tank if need arises. After neutralising the nitro-glycerine passes to an air-stirred separation and final washing tank, containing a water and soda solution, and thence to storage. Waste acid from the separator passes to a mechanically agitated dilutor, where water is added before the diluted acid is forwarded to the de-nitration plant. Here nitric acid is added and the solution is fed downwards through a tower to which steam is admitted at the base. Nitric acid is recovered at the top and returned to process as mixed acid and the sulphuric acid is concentrated to make oleum.

The plant is controlled from a desk where the operator can see the conditions obtaining at every stage of the process. There is an elaborate system of safety devices which not only gives warning when any irregular functioning occurs, but also, if no action is taken, causes automatic counteracting devices to be set in motion. Other safety measures ensure that glycerine cannot be fed into the nitrator until all the systems and services forming the process are working correctly. Different coloured lamps warn if temperatures, flows and levels of acids, coolants, &c., are at danger limit, and the whole security system is powered by a 24V d.c. battery kept charged by an automatic rectifier. A separate control room has been built with the intention of increasing the degree of safety by the installation of remote control and the use of a closed television circuit or similar means keep the operators in contact with process conditions.

After visiting the process plants we made a tour of the explosives manufacturing unit—first of all to the raw material house, where the materials are delivered at an upper floor into hoppers. At ground level a portable truck-mounted weighing machine carries a skip under the hoppers to receive the correct quantities of raw material. The contents of the skip pass through a sieve into aluminium alloy skips and are delivered to the mixing house. Here nitro-glycerine, brought in a special closed tank mounted on a rubber-tyred bogie along a "clean way," is added to the solid ingredients in a Talley mixer which handles 1600 lb of explosives per batch. The mixture is discharged to wooden skips and forwarded to the cartridge filling station, where multi-nozzle machines fill shells which have been manufactured in standard forming machines and waxed. The filled cartridges are closed, wax sealed and packed into cartons and boxes mainly by mechanical means.

General view of the Biazzi plant, showing the nitrator in the foreground, the separator and the three washers in the background

While at Ardeer, we were able to visit the testing station where the properties of certain explosives were demonstrated and testing techniques exhibited. One test concerned coal-mining explosives, and in this a 2 oz charge was fired in a large steel cylinder, which is a replica of the gallery used at the Safety of Mines Research Establishment. A 9 per cent mixture of methane and air was present in the gallery and the explosion resulting from the ignition of the fire damp/air mixture by firing a "non-permitted" explosive was contrasted with the safety with which a much larger charge of a "permitted" explosive may be fired, without igniting the gas. The old lead block test for assessing the power of an explosive by exploding a charge within the block and comparing the volumes of the charge space before and after detonation was on view, and also the latest device known as the ballistic mortar. In this a pendulum weighing about 1028 lb has a mortar attachment from which a shot is fired by a small explosive charge, and the resultant angular displacement of the pendulum records the standard strength of the explosive in degrees.

Research on blasting in coal mines is still seeking to perfect safer methods. One of these is the "Hydrox" device, consisting of a steel cylinder containing a chemical charge which, upon being ignited, burns at a controlled rate to produce gas. At a predetermined pressure the gas is released, by breaking a bursting disc, to blast the coal, there being no danger of igniting fire-damp or coal dust since the gas, a mixture of nitrogen and water vapour, is chemically inert and too cool. Recent developments allow the tube to be reloaded at the coal face and the safety of the charge was demonstrated as was the effect of the gas when released by the bursting of the disc. Pulsed infusion firing, in which a pressure impulse is set up in water by the firing of an explosive charge, was illustrated. In this an explosive named "Hydrobel," which will propagate under high hydrostatic pressures, is involved, and tests have shown that it will fire after subjection to a pressure of 1000 lb per square inch for twenty-four hours. The principle was demonstrated by firing two small charges, one in a lead pot filled with water, and the other in an empty pot.

Annual Meeting of The Society of Chemical Industry

THE seventy-fifth annual meeting of the Society of Chemical Industry opened in London on Monday, July 9th, and concluded on Saturday, July 14th. To mark the occasion it was decided that the lectures given should deal with the theme "Achievements of Industrial Chemistry," and that the speakers should review the progress made in the last quarter of a century in the application of science to chemical plant, processes and products. On the Monday evening a reception was held in the Guildhall and on the Tuesday morning there was a ceremony of presentation of congratulatory addresses by the delegates from learned societies in Britain and abroad, followed by a luncheon at the Dorchester Hotel. In the evening of the same day there was a reception by the directors of Shell Chemicals, Ltd., at the Savoy Hotel. The opening lecture was given on the Wednesday morning and the annual dinner of the Society was held on the same day at the Dorchester Hotel. Four lectures, two upon the subject of "Products of Industrial Chemistry" and two dealing with the "Tools of Industrial Chemistry," were given. Overseas visitors were entertained to luncheon and in the evening the directors of the Distillers Company, Ltd., held a reception at Londonderry House. On July 13th, four more lectures, grouped as arranged for Thursday, were presented in the morning and in the evening a reception was given by Imperial Chemical Industries, Ltd. Throughout the week members and guests had the opportunity to visit various works, while a large number of social excursions were also arranged, together with visits arranged for the ladies. The meeting closed with social excursions, which included a visit to the Glyndebourne Opera and to the Covent Garden Opera House.

RECONSTRUCTION OF RAILWAY BRIDGE.—A bridge, which was opened for use by the South Durham and Lancashire Railway in 1861 on the line from West Auckland to Tebay, has been partially rebuilt. Originally it was built to carry a single line over the road, but at a later date, 1876, the track was doubled and the arch was then widened, but not keyed to the original work. The older, more solid, bridge was still in good condition, but it became necessary to replace the faulty, newer, arch by a slab deck, and at the same time waterproof the whole of the bridge. Consultation with the Nobel Division of I.C.I. confirmed that the newer part could be blown up without damaging the older part, which was to be retained. The demolition was successfully carried out on the second Sunday possession of the site, the whole operation being completed by 3 a.m. on the Monday morning. Subsequently the abutments were built up to their new level and on another Sunday the temporary deck was replaced by a permanent slab deck which was precast in four sections. The work was completed by waterproofing this new slab as for the arch, and rebuilding the south parapet wall. This work was done by the North Eastern Region of British Railways.

High-Pressure Hydrogen-Oxygen Fuel Cell

By F. T. BACON* and J. S. FORREST.†

We reproduce abstracts from the paper entitled "Recent Research in Great Britain on Fuel Cells," presented at the fifth World Power Conference. The original paper (the conference reference is 119 K/4) reviews various kinds of fuel cells which are being investigated, but only one of them, the hydrogen-oxygen cell, is described in this abstract.

THE principle of operation of the hydrogen-oxygen cell is simply a reversal of the process of the electrolysis of water ; electrical energy is generated during the oxidation of hydrogen to water. The two inert electrodes are kept saturated with hydrogen and oxygen respectively and thus behave as gas electrodes, the gas being consumed while the material of the electrode remains unchanged.

The operation of the cell can be described in more detail as follows :—Oxygen molecules are adsorbed on the surface of the positive electrodes ; this adsorbed layer of gas is more active than molecular oxygen and is free to combine with the water present, forming two hydroxyl ions ; hydroxyl ions have a single negative charge, so that each ion as it is formed removes one electron from the oxygen electrode. Each hydroxyl ion migrates into the electrolyte and travels across to the negative electrode, where it combines with the hydrogen adsorbed on that electrode to form water, depositing an electron in the process. Since the hydrogen electrode is now negatively charged with respect to the oxygen electrode, a current will flow in the external circuit. The reactions at the inert electrodes, which may be composed of activated carbon, nickel or other materials, are thus as follows :—

Hydrogen electrode (negative pole): $H_2 = 2\,H.$
$2\,H + 2\,OH^- = 2\,H_2O + 2\,e.$

Oxygen electrode (positive pole): $\frac{1}{2}O_2 = O,$
$O + H_2O + 2\,e = 2\,OH^-.$

Overall cell reaction : $H_2 + \frac{1}{2}O_2 = H_2O.$

Under some conditions it seems probable that hydrogen peroxide, H_2O_2, is formed instead of water, but this represents a loss of efficiency and is therefore to be avoided if possible.

The theoretical voltage, which falls with increasing temperature and rises with increasing pressure, is simply the free energy of the reaction per gramme-mol of water formed at the temperature and pressure used, divided by 2 F (F being the faraday, or 96,500 coulombs), the charge carried across the cell in the formation of this amount of water.

The hydrogen-oxygen cell was first described by Sir William Grove in 1839. Fifty years later, particularly good results were recorded by Mond and Langer, who achieved a current density of 6·5mA per square centimetre at 0·73V, using either oxygen or air ; this corresponds to a useful efficiency, based on the total heat of the reaction, of nearly 50 per cent. Further progress was prevented largely because of the high cost of the platinum electrodes. The interesting work on the same type of cell by Davtyan, in the Soviet Union, was published in 1947.

Davtyan simplified Mond and Langer's construction and replaced the platinum electrodes by active carbon impregnated with finely divided metallic catalysts and used an electrolyte of 35 per cent potassium hydroxide. The carbon powder was bonded into electrodes with rubber solution and these were clamped on either side of the electrolyte compartment, hydrogen and air being passed over the back of the negative and positive electrodes respectively. The gases diffused towards the electrode-electrolyte interface and were there adsorbed and ionised.

A cell of this type was studied in the C.E.A.'s research laboratories at Leatherhead. The cells were originally constructed for demonstrations, for which this type is particularly suitable, since little auxiliary apparatus, such as furnaces, is required.

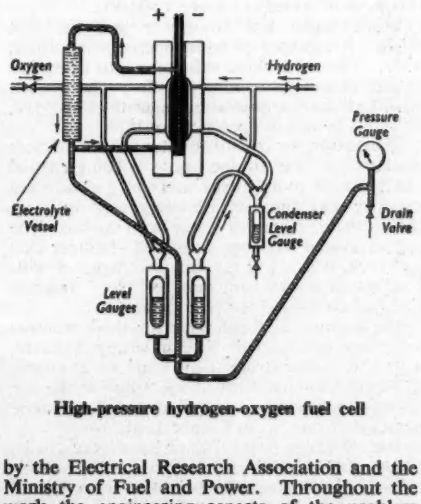
A problem encountered with this type of cell is to prevent the electrodes being flooded, since if this occurs the processes of gaseous diffusion and adsorption would be hindered. Various oils and waxes were tried as waterproofing agents, but were quickly attacked by the strong potassium hydroxide solution. Eventually, semi-permeable membranes of silicone-varnished glass cloth were interposed between each electrode and the electrolyte ; the concentration of the hydroxide solution was also reduced from 35 to 18 per cent. By this means it was possible to operate cells for several months before the membranes had to be replaced and, in fact, two cells were used intermittently over a period of nineteen months without such replacement. At the end of this time the cell e.m.f. had fallen from 0·73V to 0·2V. The presence of the membranes increased the internal resistance of these cells to at least five times the values recorded by Davtyan, and the voltage dropped from 0·73V on open circuit to 0·39V at a current density of 1mA per square centimetre.

The low e.m.f. and high internal resistance of these cells were considered to be substantial obstacles to further development. On the other hand, the comparatively slow deterioration of the cells during a period of more than a year suggested that the anticipated difficulties due to electrode poisoning by impurities in hydrogen and air may not be serious.

The High-Pressure Hydrogen/Oxygen Cell

The present work at Cambridge on this cell was commenced in 1946, though some preliminary work was started on a very small scale in 1932 and continued up till 1941, when it had to be interrupted owing to wartime difficulties.

The work is being financed by the Electrical Research Association and, more recently, jointly by the Electrical Research Association and the Ministry of Fuel and Power. Throughout the work the engineering aspects of the problem have been kept in mind, the final aim of the work being to build up batteries of perhaps 100 or more cells in series on the lines of a filter press ; moreover, since temperatures and pressures well above atmospheric were envisaged from the start, it was important that engineering principles regarding joints, pipe connections, &c., should be adhered to, if constant failures were to be avoided.



High-pressure hydrogen-oxygen fuel cell

It was also decided that no rare metals, such as platinum, should be used, on account of cost; nickel has been used almost exclusively for electrode material in conjunction with an alkaline electrolyte ; this has led to operating temperatures well above 100 deg. Cent. in order to obtain reasonably high current densities, and this in turn has led inevitably to operating pressures well above atmospheric.

It should perhaps be emphasised that gases are particularly suitable as active materials for electro-chemical cells, as they can be led in through small bore pipes ; also they are electrical insulators, so all the cells in a battery can readily be supplied from one common gas main. Liquid electrolytes, as opposed to solid electrolytes, also have many advantages, particularly in that they can be made to provide a very large area of contact with the internal surface of porous electrodes.

Several different kinds of cell have been tried, and they have led up to the present design which is illustrated herewith. The electrodes are made of porous sintered nickel and the main cell parts are of nickel-plated steel or pure nickel ; the electrolyte is strong caustic potash solution. The normal operating conditions are 200 deg. to 240 deg. Cent. and 42 kg to 56 kg per square centimetre.

The porous nickel electrodes, which are about 4mm thick, have a pore size of about 30 microns on the gas side and a thin layer of much smaller pores on the liquid side ; a small pressure difference is set up in the apparatus across each electrode, so that the liquid is expelled from the large pores on the gas side, but cannot bubble through the smaller pores on the liquid side owing to the surface tension of the liquid. It is thus unnecessary to use a diaphragm between the electrodes, a great practical advantage, and the interior of the 30 micron pores, which must presumably be wetted throughout with the electrolyte, presents a very large surface for adsorption of gas.

At present, owing to the small size of the units so far constructed, heat has to be applied externally by electric heaters, to keep the cells at the working temperature ; but it is believed that in sizes greater than, say, 1kW to 2kW, the internal losses when on load will be great enough to keep them up to temperature. In large sizes cooling would have to be used.

When running for long periods on load it has been necessary to incorporate a device for removing the water formed. The hydrogen is encouraged to circulate past the backs of the hydrogen electrodes, where it picks up water vapour which evaporates rapidly from the porous surfaces ; the mixture of hydrogen and water vapour is cooled externally, and the condensate is collected in a trap and released to atmosphere from time to time. When running a single cell at a current of 30A, about 10 ml of water are formed per hour, so the actual amount of condensate to be dealt with is quite small.

The performance of the cell improves with both temperature and pressure, but in order to attain a life of some thousands of hours it may prove desirable to limit the working temperature to about 200 deg. Cent. The best performance obtained so far at 200 deg. Cent. and 42 kg per square centimetre is shown in the table. In considering these figures it should be noted that the working current density in a lead/acid accumulator is 10–50mA per square centimetre.

Characteristics of High-Pressure Hydrogen/Oxygen Cell

Current density, mA/cm²	0	10	100	250	500	679 (max.)
Voltage, volts ...	1·10	1·02	0·905	0·805	0·677	0·585

Under typical operating conditions of 0·8V and 260mA per square centimetre, the power output per unit of internal volume corresponds to 300kW per cubic metre. The highest open-circuit voltage has been 1·168V at 200 deg. Cent. and 42 kg per square centimetre, the theoretical voltage under these conditions being about 1·20. The current efficiency has been measured over a period of some hundreds of hours, and works out at about 98 per cent. This means that the energy efficiency, based on the free energy of the reaction, will approximate, at any useful current density, to the voltage efficiency ; e.g. at 0·9V, and 200 deg. Cent. and

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† Director of Research Laboratories, C.E.A.

42 kg per square centimetre the energy efficiency will be $\frac{0{\cdot}9}{1{\cdot}20} \times 100 = 75$ per cent, and at 0·8V it will be 66 per cent.

When running on load at 200 deg. Cent., the losses, which appear in the form of heat, are mainly due to the irreversibility of the electrode reactions, or what may be called activation polarisation ; a smaller proportion of the losses are due to resistance and concentration polarisation. On open-circuit, and at low current densities, there will, in addition, be a "lost current" due to diffusion of the two gases in solution through the electrolyte, followed by combination on the opposite electrode.

Until recently, a great deal of trouble has been experienced owing to the gradual oxidation of the oxygen electrode, leading first to a drop in output and finally to complete breakdown. This trouble has now been largely overcome by using a pre-oxidation treatment at a high temperature in air, before inserting the electrode in the cell. Lithium atoms are incorporated into the crystal lattice of the nickel oxide, thus converting the ordinary green nickel oxide, which is an insulator, into a black double oxide of nickel and lithium, which is quite a good semiconductor. Using this technique, oxygen electrodes have been in operation in the cell for periods of up to 1500 hours at 200 deg. Cent., without failure.

A number of cells have been built up in series, on the lines of a filter-press, and it has been shown that the shunt currents between cells, with a common electrolyte system, are relatively small. A battery of six cells in series was shown in operation at the Production Exhibition in London, in July 1954, and with this it was possible to run small 6V motors and light a number of 6V motor-car headlamps. The maximum output obtained was 150W. It is hoped that finally each cell will be no more than 14mm thick.

Consideration is now being given to the development of automatic devices to control the amount of gas introduced under all conditions of load, to remove water by the method mentioned above, and to keep the temperature constant in larger units that will maintain the working temperature without external heating. A method of heating up from cold will also have to be worked out, for units isolated from the mains. The next step will be to design a prototype battery, large enough to have some practical application.

It is not proposed at present to use the cell reversibly, both to generate and consume the gases ; these will probably be obtained from standard electrolysers. It is hoped that eventually high-pressure electrolysers, possibly also operating at temperatures above 100 deg. Cent., will become available ; this would improve the overall efficiency of the whole process very much, but even so it is unlikely that the overall efficiency of the double process will reach that usually quoted for the lead/acid accumulator, namely 75 per cent. It is also unlikely that the cell could compete with existing small accumulators owing to the excessive heat losses, which it is believed would make the cell uneconomic in sizes smaller than about 1kW to 2kW. The hydrogen-oxygen cell will probably extend the field of electrical storage rather than displace existing methods. If it is found that pure hydrogen can be produced more cheaply in the future, either as a by-product in some chemical process, or else by electrolysis, this would improve the economic prospects of the cell considerably.

The energy to weight ratios will, however, become progressively better as the length of time of discharge at full load is increased. If a large capacity at a given power is required, the main part of the weight will be in the storage cylinders, the total weight of which would be about 7 kg per killowatt-hour of available energy at a discharge voltage of 0·8V, assuming that alloy steel cylinders are used.

The weight of gas storage cylinders, and the fact that oxygen must be carried, instead of drawn from the surrounding atmosphere, makes it unlikely that the cell will ever compete on a weight basis with internal combustion engines. When comparing the energy efficiency of the cell with that of a heat engine, the total heat of the reaction, rather than the free energy, should be taken as a basis ; the maximum possible efficiency of the cell will then be about 67·5 per cent at 1V, 61 per cent at 0·9V, and 54 per cent at 0·8V. These efficiency figures do not take into account the surplus heat, which might be put to good use in certain applications.

The probable advantages of the hydrogen-oxygen cell can be summarised as follows. It is able to take large overloads at reduced efficiency, and the low-voltage direct current produced makes it inherently suitable for traction purposes. Furthermore, it is silent and free from vibration in operation and the "exhaust" is only water. The dimensions of the cell itself depend on the power output and not on the amount of energy stored. It is believed that for outputs above 1kW to 2kW, and discharge times at full load of more than 1 or 2 hours, the cell itself plus storage cylinders would be lighter and more compact than ordinary accumulators storing the same amount of energy. Moreover, the "charging" process would merely consist of refilling the storage cylinders, a very rapid process.

Progress of No. 1 reactor house structure at Chapel Cross. The biological shield walls form an octagon and are 7ft thick. They are separated by a 6in air gap from a 6in steel plate

Constructional Progress at Chapel Cross Nuclear Power Station

THE civil engineering work on the Atomic Energy Authority's new nuclear power station at Chapel Cross, near Annan in Dumfriesshire, is now several weeks ahead of schedule we are informed. The first concrete for the foundations of the station's No. 3 reactor was placed recently. The consulting engineers for the Chapel Cross station are Messrs. Merz and McLellan. The Mitchell Construction Company is the main civil engineering contractor and its contract for this work is valued at about £3,500,000.

Work began last November and the first reactor is expected to be in operation by about 1959. The other three will come into operation at intervals of six to nine months. The station, which will have a generating capacity of 160MW, will thus be in full operation by 1961.

Excavation for the substructure of the nuclear reactors and the turbine house is being carried out by seven mobile excavators of ¾ cubic yard capacity and dumpers are being used to carry the excavated materials ¾ mile from the site. The soil excavated has been principally boulder clay and rock, which was reached at a depth of 35ft. Excavation is now complete for No. 2 reactor, and half completed for No. 3 reactor.

The biological shield walls for these reactors are being constructed of high-density concrete, aggregate being from two sources—a quarry the contractor has opened specially for the job about 8 miles away, and high-density Whinstone aggregate from North Cumberland.

The shield for No. 1 reactor has now reached a height of about 60ft and is shown in the accompanying illustration. The height when completed will be 100ft. It has a reinforced concrete wall 7ft thick separated from 6in steel plates by an air gap of 6in. There will be four heat exchangers for each reactor. The foundations for the four heat exchangers for No. 1 reactor have been excavated and foundations are being laid.

Concrete is provided on the site at a batching plant which has a capacity of 30 cubic yards per hour. Truck mixers carry the concrete to the reactor sites, and we are informed that their use enables mixing time at the batching plant to be reduced, thus increasing the output of the plant by as much as 75 per cent. The average weekly output from the batching plant is 1500 cubic yards. At present four 10-ton derricks are in use, mounted on gabards 40ft high. It is expected that two derricks will be used on the construction of each of the four reactor houses. To supplement these, a 15-ton mobile crane with an 80ft beam is used.

Besides the work on the reactor houses, the contractor has completed the foundations and floor of the turbine house and is working on the construction of the floor of a hangar (Chapel Cross used to be a Royal Air Force airfield) where the heat exchanger vessels will be fabricated and tested, and is also laying the foundations for workshops where the reactor pressure vessels will be welded. A complete network of service roads was recently completed.

Four cooling towers, each 300ft high, are to be built at Chapel Cross. Work on the foundations for the cooling towers has been going on for more than a month and 6000 cubic yards of material has been excavated, and some concrete placed. Excavation for the substation site has also been completed, mass concrete has been laid for the foundations, and precasting of the special units required for the switchgear has begun. At the present moment 400 people are engaged in the constructional work, about half of whom are drawn from the locality.

CANONBIE COALFIELD.—The National Coal Board has put down four boreholes to explore the extension of the Canonbie Coalfield, which lies on the boundaries of England and Scotland. Workable reserves of coal have been proved and in due course a colliery may be sunk to work them, but for the present the Board's resources are fully engaged in the exploitation of proved reserves in other coalfields. The coalfield consists of an exposed field around Rowanburn and Byreburnfoot, lying to the north of Canonbie village, in which the seams have been extensively worked at comparatively shallow depths ; and a concealed field around Canonbie itelf, where the coal-bearing strata are overlain by a considerable thickness of non-coal-bearing strata. The exposed field was formerly worked at Rowanburn (seven seams) up to 1922, and there are much older workings at Byreburn (three seams). At Rowanburn the seven seams ranged in thickness from 3ft to 9ft and their total thickness was 36ft, distributed through 330ft of strata. The depth to the lowest seam at the Rowanburn engine pit was 464ft. The three borings put down recently by the Board at Knottyholm, Rowanburnfoot and Crookholm have shown that the Rowanburn succession of coals extends over an area of at least 2½ square miles. The depth of the shallowest of the workable coals at Knottyholm and Rowanburnfoot is respectively 1386ft and 1713ft, compared with only 137ft at Rowanburn.

Electrification of a Welsh Grit-Stone Quarry

ELECTRIFICATION forms part of an extensive modernisation and expansion programme in the Alltgoch Quarries of the Anglo-American Asphalt Company, Ltd., near Llanybyther in Carmarthenshire, where the quarry plant had previously been driven by diesel engines. Conversion to electric drives was made on the basis of individual motors for each item of plant, either through reduction gear boxes or V-belts. The contract for the supply and installation of the electric equipment was placed with The English Electric Company, Ltd., the cabling and installation being carried out as a sub-contract by the Towy Electrical Company of Drwystyn, near Llandilo.

Stone from the adjacent quarry is taken by dumpers to a chute and plate feeder before entering the primary crusher—a Baxter 26in by 24in machine, which is driven through V-belts by a 75 h.p. induction motor (Fig. 2). The product from the primary crusher passes on a 24in wide belt conveyor to a single-deck vibrating screen where dirt is removed from the stone, which is then stored in a 50-ton steel hopper. This stone is fed by a Locker electric vibrating feeder to two "Kue Ken" 24in by 12in secondary jaw crushers, set at approximately 2½in opening, and driven by one 50 h.p. motor. The product from these crushers is then fed by a belt conveyor to a two-way chute, from which part of the material is fed into a 3ft Simmonds Nordberg cone crusher for making chippings, and the other part is taken by a bucket elevator to a vibrating screen, which grades the stone for coated macadam into hoppers containing four sizes—¼in to dust, ⅜in to ¼in, 1½in and 2½in. The product of the cone crusher is fed by bucket elevator to two vibrating screens, which grade the chipping into four sizes—$\frac{1}{16}$in to dust, ¼in, ⅜in and ½in—and they are stored in steel hoppers of about 200 tons capacity.

Stone for the mixing plant (Fig. 1), is drawn from the dry stone hoppers into a lorry and carried to the feed hopper of the mixing plant. Bitumen for the coated macadam is stored in two 6000 gallon "Clarmac" electrically-heated lagged storage tanks, from which it is pumped to the plant, where it is carefully weighed before mixing with the stone.

Electrical Plant

The 415V, three-phase, 50 c/s, four-wire supply is obtained from a 300kVA, 11,000/415V step-down transformer and "Combination" fuse switch in a South Wales Electricity Board sub-station at the quarry edge, from where it is taken to a distribution sub-station in the quarry. The earth provided by the South Wales Electricity Board for neutral earthing of their transformer was utilised as the installation earth. Earth continuity throughout the installation was then obtained by using the good conductance properties of the double-wire armouring of the paper-insulated lead-covered underground cables and of the heavy-gauge galvanised conduit. The double-wire armouring served also as added mechanical protection to the cable, which was desirable since heavy lorry traffic crosses the trenches. In view of the difficulty in handling large armoured cables, for the long length of cable from the transformer to the sub-station, two 0·15 square inch, four-core cables were laid in parallel instead of a single 0·4 square inch cable. To ensure that the earth conductance was low (the ground being of poor conductivity), a separate copper strip was used to supplement the conductance of the armouring on the incoming cable. The incoming supply to the quarry sub-station is connected to an English Electric cubicle type air-break circuit-breaker with over-current and under-voltage trips. The breaker is manually operated and an English Electric hinged armature relay is incorporated for instantaneous earth fault protection on the system.

High-rupturing-capacity cartridge fuses are used to protect all main and sub-circuits, the air-break "Combination" fuse-switches in the distribution sub-station feeding the large crusher motors direct, and the smaller motors through weather-proof fuse distribution boards fitted with isolators, the armoured cables being run underground wherever possible for protection. Outgoing wiring from the fuse distribution boards is in galvanised conduit.

The crusher motors and the asphalt mixer motor are slipring motors, and hand-operated, dust-and-damp-protecting stator/rotor starters with integral isolators, manufactured by the Electrical Apparatus Company, Ltd., are installed to supply the necessary torque while limiting the current at starting. The crusher motors are totally-enclosed with closed-air-circuit coolings; that is, they are basically pipe ventilated with air inlet and outlet openings connected to a surface cooled radiator mounted on top of the machine. An external fan on the end of the motor shaft drives air through the tubes of the radiators to extract the heat.

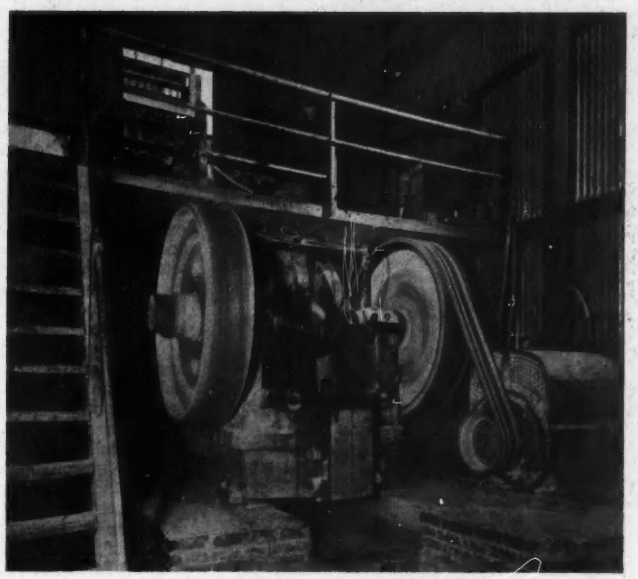

Fig. 2—Totally-enclosed pipe-ventilated 75 h.p. slipring motor driving the primary crusher

Totally-enclosed, fan-cooled squirrel-cage motors are used for all other drives, high-inertia drives and conveyors being equipped with high-starting torque motors. All these squirrel-cage motors are started direct-on, by push-button-operated, weatherproof starters fitted with integral isolators.

All fuse distribution boards and some starters are situated out of doors, sheet steel watersheds protecting them from direct rainfall.

To keep to a minimum the loss of production from the quarry during the changeover the cabling was carried out during normal working hours, and the old drives were taken out and replaced by electric motors during week-ends and holiday periods. We learn that, as a result of the electrification, which was completed over a year ago, production has increased considerably.

Fig. 1—The coated macadam plant showing (left to right) the intake conveyor, dust extraction duct, oil-fired rotary drier, mixing plant, and electrically operated tar boilers. The totally-enclosed 30 h.p. motor shown drives the whole mixing plant

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Design Research.—The July issue of the Council of Industrial Design's journal, *Design*, contains the second part of an article on design and stress analysis, which is devoted to design research. After establishing that research is conducted on a disproportionately small scale by British industry, partly because of "amateurism" in management, the author, L. Bruce Archer, points out that only one aspect of design, the consideration of production, has been the subject of adequate applied research, and that even mechanical and structural design are carried out largely intuitively. The example argued is the safety bicycle, whose conventional diamond frame has been excelled, in laboratory investigations, by examples of cross-frame pattern. The author realises that the scientific age, in the sense that science solves problems of design, is not yet with us, but looks to scientific experiment as a means of advance in design. The article is illustrated principally with photographs bearing upon bicycle design, and these do not increase its authority. Often implied comparisons are not justified, as when a distorted frame is shown without any indication of the loads under which it failed.

Ward-Leonard Control of Veneer Peeling Lathe

ON a veneer-peeling lathe recently installed at the Wallsend works of Tyne Timber and Veneers, Ltd., Ward-Leonard control is used to maintain constant peripheral speed of the log by accelerating the lathe driving motor as the log diameter decreases. Maximum output of veneer is thereby obtained from the lathe. The generator excitation is varied automatically by means of a speed regulator operated through a differential voltage relay with its coils carrying voltages proportional to the motor speed and the position of the cutter bar on the lathe.

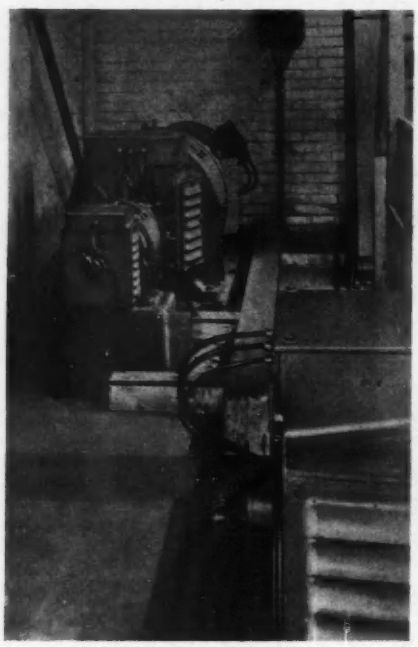


Fig. 1—Ward-Leonard set for drive of a veneer peeling lathe. The tacho-generator on the main driving motor can be seen in the foreground

The lathe (Fig. 2) which was supplied by Ritter, Fleck and Roller Maschinenfabrik A.G., Hamburg, can accommodate logs up to 130in long and 79in diameter. Veneers are peeled with thicknesses between 0·064mm and 10mm at speeds up to 700ft per minute.

The electrical drive and control system was supplied by The General Electric Company, Ltd. The lathe motor is a 70 h.p. machine which takes its supplies from a motor-generator set (Fig. 1), comprising a 95 h.p. driving motor, a 58kW d.c. generator with an output of 220/285V at 970 r.p.m., and a 5kW exciter. A cubicle switchboard houses the star-delta starter for the m.g. set and the main items of control equipment. At the operator's position on the lathe a panel is provided incorporating pushbutton controls, a feet-per-minute meter, and a speed-setting rheostat which enables the maximum speed at any position of the cutter bar to be selected according to the hardness of the wood being peeled.

After the motor-generator set has been started and the clutch between lathe and motor closed, the log can be rotated at low speed for dressing by operating an "inch" pushbutton which brings in minimum generator excitation. To begin peeling, the clutch is opened and the "start" button operated, causing a drum-type accelerator, driven by a pilot motor, to operate the accelerating contactors. The generator excitation is increased by cutting out the "inch" section of its field resistance and the lathe motor runs on full field. In this condition the clutch can be reclosed, and the motor speeded up to give the selected peripheral speed for peeling, by moving the cutter bar up to the log.

Movement of the cutter bar operates a chain-driven rheostat which, in conjunction with the speed-setting potentiometer, adjusts a reference voltage across one coil of a differential voltage relay. The other relay coil is connected across the tacho-generator on the lathe motor shaft. If the reference voltage exceeds the tacho-generator voltage, the relay contact moves to operate a raise-speed contactor which starts the speed regulator pilot motor running in the required direction until a balance is obtained. The motor arm of the speed regulator controls the same generator and motor field resistors as are involved in the action of the drum accelerator before the automatic control is initiated by movement of the cutter bar. If the tacho-generator voltage exceeds the reference voltage, a "lower-speed" contactor is operated and the pilot motor runs in the opposite direction until balance is again obtained. The motor speed is therefore closely controlled throughout the peeling operation by a combination of generator field and motor field adjustment.

When peeling is completed the clutch is opened and the motor is stopped by pressing the motor "stop" button. The speed regulator and drum accelerator then both run back to their starting positions. If either of the emergency stop push-buttons is operated, the motor stops and the drum accelerator returns to its "off" position, but the speed regulator remains at the setting corresponding to the speed appropriate to the position of the cutter bar. On restarting, therefore, the accelerating contactors rapidly bring the motor up to this speed and the clutch may be closed to resume peeling.

We learn that the installation of the new lathe and drive has enabled a useful increase to be obtained over the output from earlier equipment in which a combination of mechanical and electrical methods was used for speed variation, and control was effected by the operator.

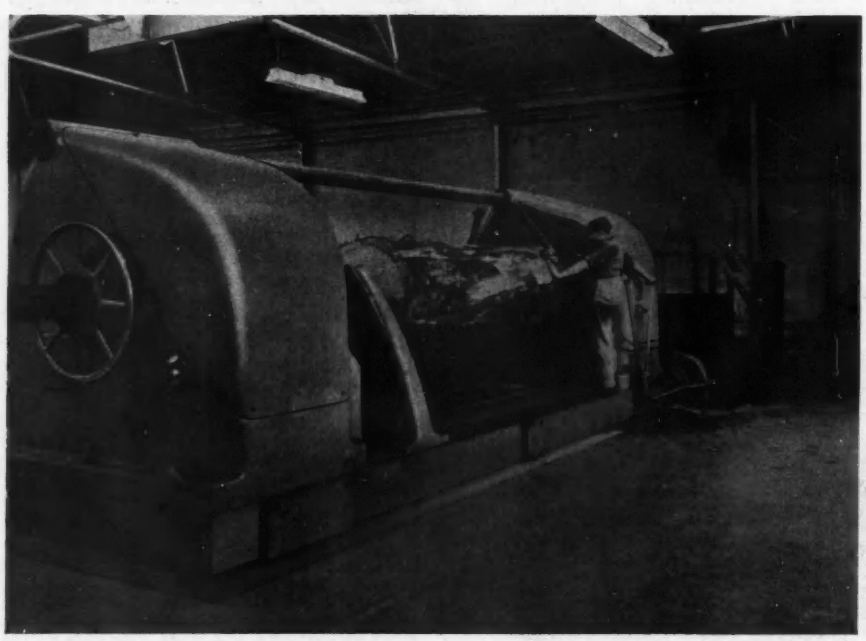


Fig. 2—Veneer peeling lathe with motor drive giving automatic speed variation to compensate for the diminishing diameter of the log as peeling proceeds

Aluminium Cable Soldering

A RECENT development by Johnson and Phillips, Ltd., Charlton, London, S.E.7, is a reactive flux offering certain advantages over organic fluxes for soldering joints in aluminium conductors. The organic fluxes at present used give only a limited degree of solder flow under capillarity, so that a number of the wires must be cut short and splayed out; they also emit noxious fumes in use. With the use of "Junal 5," these difficulties are avoided, together with the necessity to tin the conductors before assembling the joint, and to avoid overheating the flux.

The reactive flux, being hygroscopic, is supplied in tubes. It is a highly effective tinning agent for metals such as copper, but tins aluminium to the full only in the absence of air; consequently it is a characteristic of joints made with it that they are consistently good at the core of the cable and disappear where the cable is open to air. In use, the cable is stripped of insulation for about an inch beyond the intended length of the joint, smeared lightly with "Junal 5" on end and periphery, and inserted into the joint ferrule or end fitting. In the case of a joint the facing end of the other cable is kept $\frac{1}{16}$in away to allow solder to enter all over the cross-section of the conductor. The fitting or ferrule is first heated and then flooded with tin-copper-zinc solder at about 400 deg. Cent.; white smoke, which is not malodorous, is emitted when the flux becomes active, and indicates that the joint can be finished in the usual way. A temperature of 350 deg. Cent. must be attained for the flux to operate, and any further increase will be beneficial. At a demonstration it was shown that this temperature which might easily be exceeded, when soldering copper in the field, only charred the innermost paper sheath an inch from the ferrule.

Tests by sectioning and bending the conductor showed that the solder united the wires for some distance outside the joint proper and tensile tests, which we did not witness, resulted in a cable containing a joint breaking through the conductor where heating had weakened it, rather than in the joint failing. The hygroscopic properties of the flux require that the joint shall be sealed against moisture, which is recommended by the makers in case of all soldered aluminium cables; in short-term tests under damp conditions the increased joint efficiency has more than counterbalanced any accelerated chemical action. Long-term tests are in hand and are at present claimed to be favouring the reactive flux.

Metal Cleaning and Electro-Plating Factory

ON July 11, members of the Press were invited to the official opening of the factory at Sheerwater, Surrey, of the Electro-Chemical Engineering Company, Ltd. Whereas previously manufacture had been carried out at the company's Burton-on-Trent factory and by various sub-contractors, engineering work is now being transferred to the new premises, where provision has also been made for chemical mixing and packaging of chemicals for metal-plating and cleaning. The factory will be concerned with the assembly and mechanical testing of "Efco-Udylite" automatic machines, while in the laboratories the routine analysis of customers' solutions will be undertaken and new plating processes tried out and demonstrated. Some of the aspects of this work are illustrated on this page.

Situated on an L.C.C. estate on the outskirts of Woking, the factory is built on an area of 3 acres. The workshops comprise six bays, each with a span of 35ft, five of them having a length of 66ft and a height to the underside of the roof trusses of 16ft, while the sixth is 88ft long and has a clear height of 23ft. This last bay is served by a 3-ton overhead crane. A building 20ft wide and 210ft long adjoins the shops, and contains the demonstration plating shop, the analytical and development laboratories, and offices for chemists. To the north is a separate two-storey office block which is connected to the works by a covered way. It houses the design, purchasing and sales departments and the administration. Altogether, the factory has a floor area of 21,000 square feet and the office block 7000 square feet. It is intended to lay out the area adjacent to the office block as a garden and to retain as many of the existing trees as possible.

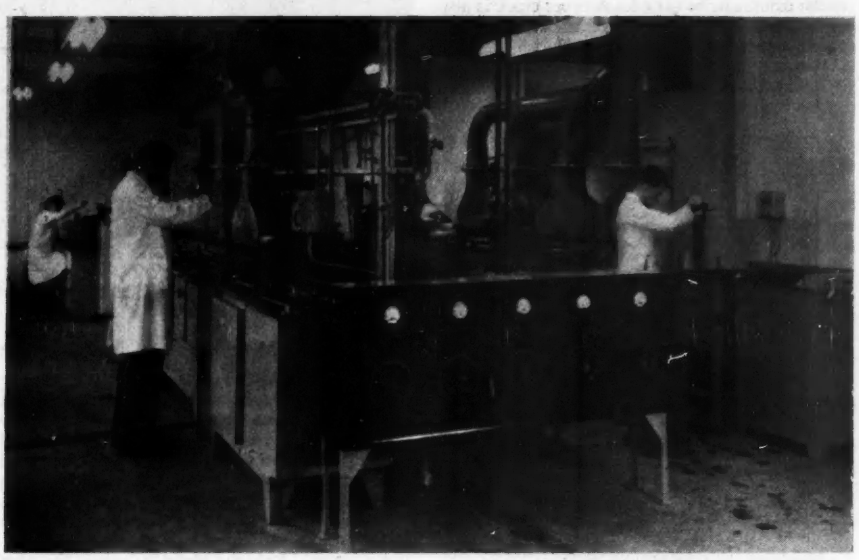
The workshop bays have a steel-framed structure, with the roofs clad with insulation board sandwiched between sheet metal on the inside and roofing felt on the outside. Without affecting headroom, this design reduces the amount of space which requires to be heated. All floors are screeded and dustproofed, or laid in asphalt in areas where acids are used.

For the office block a prefabricated design was chosen, based on a 40in module. This building consists of a lattice steel skeleton clad with reinforced concrete slabs with textured and coloured outer faces and an inner breeze skin. The flat roof is insulated and lined with prefabricated plaster slabs.

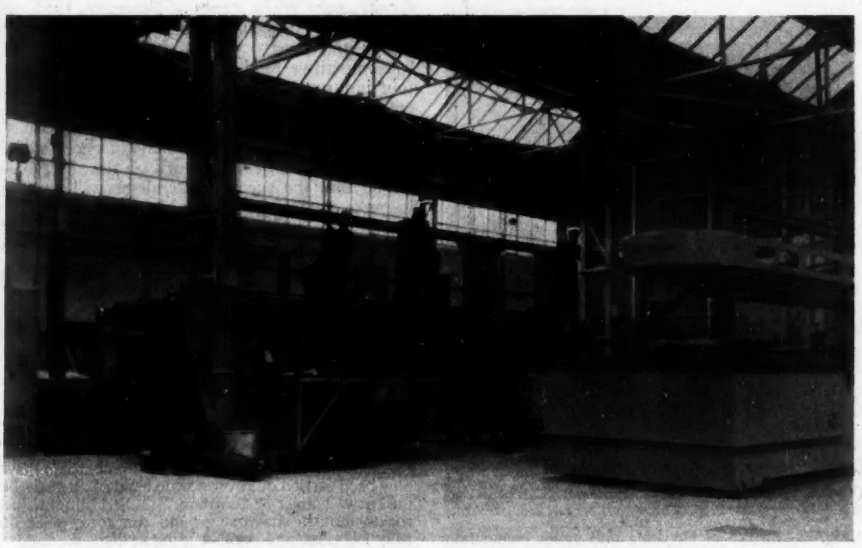
The chemical mixing platform has been designed for raw materials to be brought by fork-lift trucks and added to the various mixing tanks after measuring. After stirring, solutions are filtered and pumped to storage tanks, and filled into carboys. In view of the corrosive nature of many of the chemicals, some of the tanks are rubber-lined, while others are made of stainless steel; there is a fume-extraction system with ducting made of plastic material.

The factory possesses only a small machine shop, since most of the actual construction work is carried out elsewhere. In the demonstration plating shop provision has been made for a wide variety of electro-plating processes. Besides hot and cold water, steam, gas and low-and medium-pressure compressed air, are available as well as a.c. and d.c. The fluorescent lighting is of vapourproof design. An effluent disposal plant is installed to deal with the wastes from the chemical mixing plant and the demonstration plating shop. In the boiler-house are two oil-fired boilers for 200-seconds oil, one of them a horizontal triple-pass boiler with a rating of 2,000,000 B.Th.U. per hour. The other boiler is a vertical unit; provision has been made for an additional horizontal boiler to be installed later. Space heating in the workshops is by suspended steam heaters, while the office block has hot water radiators supplied from a steam/hot water calorifier.

In the present layout arrangements have been made to expand the factory to at least twice its present size and to increase the office block by 70 per cent. Service roads have been laid out accordingly and provide access to hard standings for the storage of drums and containers. The consulting engineers were Campbell, Gifford and Morton, Ltd., Weybridge, with T. A. Bird, A.R.I.B.A., acting as consulting architect for the office block.



Plating tanks in the demonstration plating shop



Construction of automatic plating machines

Automatic Cinematograph Projection

WE illustrate overleaf a "Projectomatic" equipment for performing automatically the main operations associated with a continuous cinematograph performance. The sequence in which the various operations are carried out is determined by the arrangement of pins set in a rotating drum, or, in the case of changeover operation, by marks on the film. Once the drum has been set up and the film marked prior to the first performance, the show will run continuously without further action by the operator other than to clean and lace the projectors, renew carbons and change discs on the non-sync.

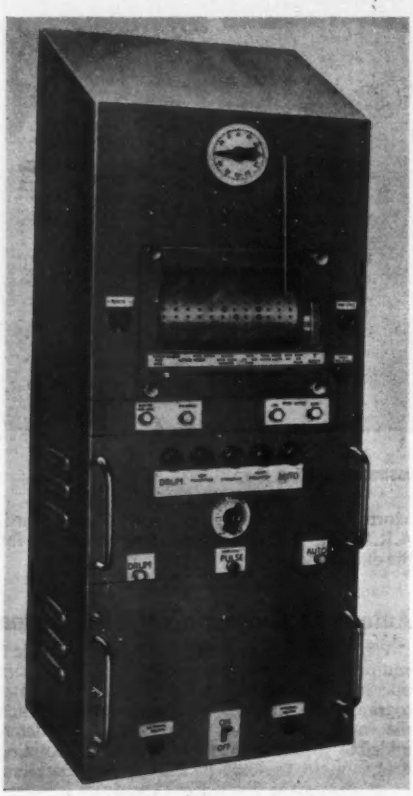
The equipment consists of a main control cabinet (measuring 29½in by 12in by 7¼in) and a number of relay units which are operated by signals received from the main control unit, and which in turn control the various switching functions on the projection equipment. In addition, special rollers are fitted on the projectors to detect the film marks and to operate an emergency stop circuit in the event of a film break or mechanical failure.

The operations which can be performed by the system can be varied to include some or all of the following:—(1) Projector motors, start and stop; (2) arcs, strike and extinguish; (3) dowsers, open and close; (4) changeover of picture and sound (single track optical or multi-track magnetic); (5) non-sync motor, start and stop; (6) amplifier system, sound on film to non-sync and vice versa (the pick-up must be placed on the disc by the operator in readiness for the automatic operation); (7) curtains, open and close; (8) footlights, dim up and down through a reactor dimmer; (9) houselights, dim up and down through a reactor dimmer; (10) screen masking for three aspect ratios. Furthermore, a colour selector system can be fitted, giving facilities for preselection of various

combinations of three colour-circuits or house-lights.

The pin drum, which is housed in the main control cabinet, is fitted with rows of holes spaced at regular intervals around its circumference. The drum is rotated in steps by a solenoid operating through a ratchet mechanism, each step being equal to the space between two adjacent axial rows of holes. Each of the thirteen circumferential rows of holes corresponds with a particular function and is associated with a microswitch which is operated by the passage pin inserted in the appropriate hole. The solenoid coil is controlled through a "Thyratron" circuit with a variable time delay, whereby the time interval between successive steps in the rotation of the drum can be varied. A timer clock is also fitted for use when a longer interval between operations is required.

For automatic changeover operation, a pin is set in an appropriate position on the drum.



Main control cabinet of "Projectomatic" system for automatic cinematograph projection

The control of the various functions associated with changeover is then entirely dependent on the film marks, and the drum has no further influence until the end of the last reel.

Where a changeover is required, three marks are placed on the film towards the tail leader. The marks are made by applying an electrically conducting lacquer to the film in the region of the perforations. When the first mark passes the detecting roller, it causes various relays to operate in the control unit and a warning buzzer sounds, indicating to the operator that a changeover is about to take place. The next mark follows within fifteen seconds' running time and operates further relays which start the motor of the incoming machine and strike the arc. The arc is struck by the direct application of power, a fusable pellet having previously been placed between the carbon tips by the operator during the unoperated period. The outgoing machine continues to run until the third mark passes the roller, when its dowser is closed, its arc lamp extinguished and its motor stopped. At the same time sound changeover takes place.

We learn that the first "Projectomatic" installation is at the Queen's Cinema, West Bromwich. The distributor of the "Projectomatic" equipment is G.B.-Kalee, Ltd., 37–41, Mortimer Street, London, W.1.

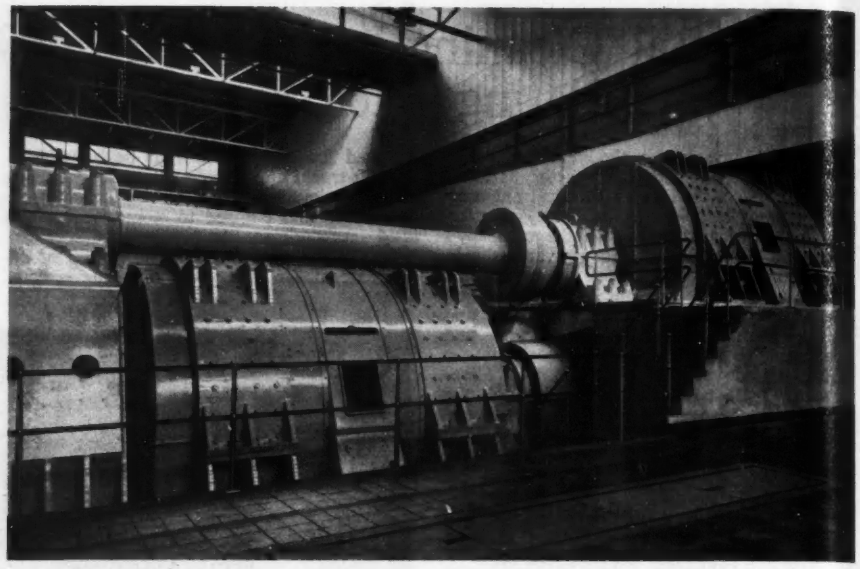


Fig. 1—9000 h.p. twin drive for blooming mills in the Abbey Works of the Steel Company of Wales

Abbey Works Slabbing Mill Drive

We have received some details relating to an electrical fault that recently caused a shut-down of the slabbing mill at the Abbey Works of the Steel Company of Wales. It will be recalled that each working roll of this mill is driven independently of the other by an English Electric, 4600 h.p., double-armature, 40 r.p.m., direct-current motor. A general view of the drive is reproduced in Fig. 1.

A statement from the Metal Industries Division of the English Electric Company, Ltd., points out that the fault occurred on the driving-end armature of the lower machine and that two commutator risers were burnt out as a direct result of a short-circuit on the surface of the commutator, about 3in from the inboard edge. The statement goes on to explain that the risers are individually taped, that the insulation was destroyed down to the root of the riser, and that the risers immediately adjacent to those carrying the short-circuit current were also destroyed by the subsequent arcing. The photograph reproduced in Fig. 2 was taken after the short-circuit between the two bars had been cleared, and it shows a close-up view of the surface of the commutator adjacent to the point at which the short-circuit occurred.

According to the company's statement, the groove that can be seen in Fig. 2 was about 0·020in (maximum) in depth, circular in cross section, and extended completely round the commutator from the point at which the short circuit occurred. All the gaps between the commutator bars were "burred" to varying extents at the groove, but a short circuit existed only between the two bars connected to the burnt-out risers. The statement concludes that it is certain that the trouble was caused through some metal object coming into contact with the commutator and burning up the risers.

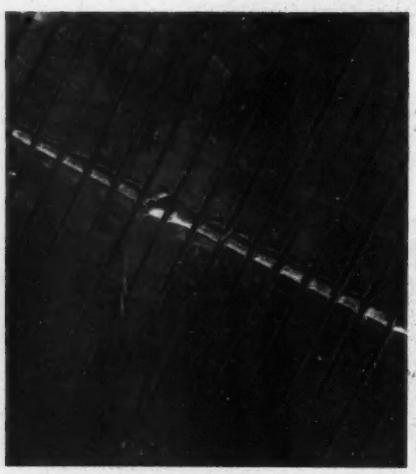


Fig. 2—Surface of blooming mill motor commutator near to the point at which the short circuit occurred. The photograph was taken after the short circuit between the two bars had been cleared

Bradwell Nuclear Power Station

We learn that the Central Electricity Authority has received from the Minister of Fuel and Power his consent to the establishment of the proposed nuclear power station at Bradwell, in Essex; it will be recalled that the Authority's application to build this station was the subject in April of a local inquiry lasting four and a half days at Bradwell and Maldon, Essex. The Minister's consent is for the erection of a nuclear power station containing turbo-generator sets having an aggregate electrical output of about 200MW, and two carbon-dioxide-gas-cooled, graphite-moderated reactors, together with the necessary buildings and civil engineering works. It will be the first large nuclear power station designed specifically for public electricity supply and the first of the twelve stations envisaged in the Government White Paper of February, 1955, on the nuclear power programme. The detailed design and construction of the station are open to competitive tender and the proposals of the four industrial groups of manufacturers who are entering this new field are due in October. Necessary preliminary works, including the provision of road access, are being put in hand at once so that there will be no delay in work on the site. It is hoped that the successful tenderer will be able to make a start early in the New Year.

In view of the fears that have been expressed about the possible effects of the operation of the power station upon the local oyster industry, the Central Electricity Authority intends to keep the problems of the industry under constant review. To this end it has undertaken to co-operate with the Fisheries Department of the Ministry of Agriculture, Fisheries and Food in a continuing study of conditions in the Blackwater Estuary.

Aircraft Rocket Motor.—Flight trials have now been carried out over a wide band of altitudes on the new Napier "Scorpion" N.Sc.1 liquid fuel rocket motor. Its first ground run took place on May 19th last, and the first firing in flight the following day. An English Electric "Canberra" aircraft was converted to test the rocket by the Napier Flight Development Establishment.

Industrial and Labour Notes

Private Industry and Prices

On Thursday of last week, a statement on inflation and prices was made jointly by the Federation of British Industries, the National Union of Manufacturers, the Association of British Chambers of Commerce, and the British Employers' Confederation. These organisations suggest that "a moment has come when private industry can and should play a special part in defeating inflation."

In the statement, the four organisations say that, while the urgent need remains for resolute action in reducing public spending, the Government's measures to stop inflationary pressure at its source appear now to be having some effect. The boards of the nationalised industries, without whose co-operation private industry can do little, the statement continues, have announced measures to steady the prices of their products for substantial periods. The four organisations then express the "strong view that this is the time when private industry, in its own as well as the national interest, should do what is in its power to match these actions." But their statement adds that general guarantees of price freezing are not possible when costs of materials may rise. Quotations for many manufactured products, unlike those for coal, power and transport, are made for deliveries months or years ahead. Nevertheless, it is urged, this is a moment, when an exceptional risk must be accepted, and the signatories to the statement say that they "advocate and will support a policy of great restraint in a united effort to bring inflation to an end." This part of the statement ends by saying that price restraint will not succeed unless the breathing space which it gives is used to bring down costs. The months immediately ahead, therefore, will have to be devoted with renewed vigour by all in industry to the pursuit of higher productivity and administrative economies.

To the main statement, the British Employers' Confederation has added a comment on the related question of wages. It says that the nation now has a real opportunity to free itself from constantly rising prices and the consequent fall in the purchasing power of money. To that end, "co-operation from all is needed." Steadiness in prices depends on steadiness in costs, the Confederation remarks, and wages are a major element in costs. The greatest benefit to the community will come, the Confederation points out, if the money in pay packets can be made to buy more.

Iron and Steel

The Iron and Steel Board has stated that British steel production in June averaged 379,700 tons a week, compared with an average of 412,700 tons a week in the preceding five months of the year. The fall was caused mainly by the ban on overtime which maintenance workers in the steel industry have imposed. In the second quarter of this year, steel production totalled 5,185,000 ingot tons (compared with 5,413,000 tons in the first quarter), and the Board says that the loss of production through the overtime ban in the second quarter has been estimated at 300,000 tons. Pig iron output in June averaged 239,600 tons a week, compared with 246,500 tons a week in May. The annual rates of production during June of steel (19,744,000 tons) and pig iron (12,459,000 tons), however, were higher than in the comparable month of last year, when output was affected by the railway strike. Over the first six months of this year, steel output was at an annual rate of 21,196,000 tons, compared with a rate of 20,149,000 tons in the first half of 1955.

The Board reports that the demand for steel continues to be high, particularly in the case of plates, joists and heavy sections, which are mainly required, of course, for shipbuilding and constructional engineering. The lighter products, including cold rolled strip and wire rods, are in less demand, as are sheets for some durable consumer goods. The Board adds the comment that the change in relative emphasis from consumer goods to capital construction and exports persists. As to raw materials, it is reported that supplies in the first half of this year were adequate to production needs. Stocks of iron ore are now being built up following a reduction of supplies in the earlier months of the year when imports were lower than planned as severe weather in the Baltic reduced supplies from Sweden and political difficulties affected supplies from French North Africa. At the end of June, stocks of imported ore were 1,461,000 tons, compared with 1,035,000 tons a year earlier.

Last week in these notes we recorded the Minister of Labour's decision to set up a court of inquiry to examine the circumstances of the iron and steel maintenance workers' wage dispute. The National Joint Trade Union Craftsmen's iron and steel committee had recommended strike action as from last Saturday. But when the committee met last week it decided to postpone indefinitely the threatened stoppage, though it agreed that the ban on overtime should continue. Meanwhile, the Minister of Labour has announced the membership of the court of inquiry. Sir John Stewart is the chairman, and the two other members are Brigadier L. C. Mandleberg and Mr. C. J. Geddes.

The Factory Inspectorate

On Monday, there was a debate in the House of Commons on the administration of the Factories Acts. During that debate, Mr. Robert Carr, Parliamentary Secretary to the Ministry of Labour, said that, excluding certain senior posts at headquarters, the authorised strength of the general factory inspectorate was 322, compared with 309 at the end of the war. The change had been accounted for largely by the addition of about a dozen inspectors in 1948 to cope with extra work arising out of building regulations. The difficulty since the war, Mr. Carr explained, had been to recruit up to the full establishment. In 1947 there were 100 vacancies, by 1950 the shortage was still fifty-six, by 1953 it had been reduced to fourteen, and at present the inspectorate was, at last, virtually at full strength.

The Parliamentary Secretary went on to say that considerable criticism had been made of the inadequate size of the factory inspectorate. He submitted, however, that it was useless to talk about increasing the establishment until some factual evidence had come forward that it was possible to maintain even the present one. In the last two or three years, that position had been achieved, and the time had come to think about whether the establishment was adequate, and to look to the future, which was what the Ministry had been doing. One of the most controversial points raised in the debate, Mr. Carr continued, was that of the qualifications required by recruits to the factory inspectorate. What proportion should come in with technical qualifications and what proportion should be men and women with degrees in non-technical subjects? He thought it was generally agreed that there should be a mixture of both kinds. The "argument" concerned the proportions of the mixture. The factory inspectorate could never be sure of sending the right specialists to the right factories, even if it had an unlimited supply of them. That, Mr. Carr submitted, applied more and more as industry became more and more technically complicated and more and more specialised. The work of the general inspectorate certainly required a knowledge of technical matters but it was in itself an executive job, and did not involve an inspector actively practising his technique, say, as an engineer or as a chemist.

But, Mr, Carr added, every effort would be made to increase the interest of potential candidates for the inspectorate who had technical qualifications. The Minister of Labour proposed to increase the number of factory inspectors by such stages as were practicable in relation to recruitment and absorption. In the first place, the strength of the engineering and chemical branch, at present eighteen, was to be increased to at least forty-four. Subject to further consideration in detail, that would enable one engineering inspector and one chemical inspector to be stationed in each division. In addition, there was to be some reinforcement of the general inspectorate, in order particularly to enable the inspectors to pay more attention to building operations and works of engineering construction.

Redundancy in the Motor Vehicle Industry

On Tuesday, representatives of the employers and unions concerned in the dispute, following the dismissal of 6000 workers from the British Motor Corporation's factories, met the chief industrial commissioner of the Ministry of Labour. This meeting resulted from an invitation extended by the Minister of Labour. Early last week, representatives of the unions concerned passed a resolution recommending their executive councils that strike action, dating from Monday, July 23rd, should be taken in all the British Motor Corporation's factories. When the Minister of Labour, Mr. Macleod, was questioned in Parliament last week about the dispute, he emphasised that negotiating machinery was available in the industry. It had been the policy of Ministers of Labour, he said, that they did not in any way attempt to weaken that machinery, and that intervention was called for only after the machinery had been fully used and exhausted. As we go to press, it has been stated that last Tuesday's conversations at the Ministry had not led to a solution of the dispute.

Coal

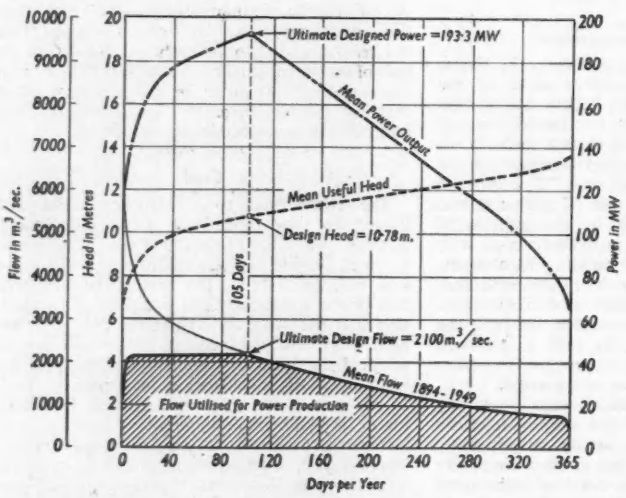
The reports made to the Minister of Fuel and Power by the Industrial Coal Consumers' Council and the Domestic Coal Consumers' Council, for the year ended June 30, 1956, have now been published. The first of these reports, that of the Industrial Coal Consumers' Council, says that the main concern in the past year has been that costly expedients have had to be adopted to meet the rising inland demand for fuel, and that pithead prices have risen by over 25 per cent in all. After making due allowance for all the difficulties inherent in replacing and increasing capacity in an extractive industry and increasing production from the low post-war level, the council considers that the gap in indigenous fuel supplies could be narrowed if full advantage was taken of suitable available labour from overseas. The hope is, therefore, expressed, in the interest of the nation and for the well-being of the coal industry itself, that the National Coal Board and the National Union of Mineworkers "will seek to overcome any remaining obstacles to the adoption of this course and to the achievement of the full benefits of mechanising the pits."

Referring to the latest increase of 8 per cent in the pithead price of coal, the Council says that the Coal Board, after a full explanation of its difficulties, "convinced us of the necessity for the increase." But, the report continues, "we deplore the necessity for the increase because both directly and indirectly it will tend to increase the production costs of industry generally and impair its competitive ability." The council then observes in its report: "some of us were strongly of the opinion that the increase should be tempered by clearing the deficit over a longer period. On this our opinions were divided and we were unable to advise that the increase should be on a lower scale. Incidentally, we consider it somewhat illogical that a large part of the deficit, which has to be met by higher prices to the detriment of industry generally, should be due to the payment by the nationalised coal industry of income tax and profits tax. We would add that it is not always realised that we are not empowered to control the Board's expenditure and, apart from advising some alternative policy where that appears to us to be both practicable and desirable, we can only acquiesce in the National Coal Board's proposals, however distasteful they may be to the consumers we represent."

Ybbs-Persenbeug Hydro-Electric Scheme on the Danube

Progress in the construction of a large run-of-river hydro-electric scheme on the Danube, in Austria, is described. The scheme will generate 1252 million kWh annually, from an installed capacity of about 190MW; two navigation locks, each 230m by 24m in size, form part of the scheme. Some points of special technical interest are described.

AUSTRIAN hydro-electric construction is at present concentrated on a group of high-head schemes in various mountain regions, and also on exploitation of the Danube, where a series of run-of-river stations will eventually be constructed along that length of the river which lies in Austrian territory. One power station, a joint venture shared by Austria and Germany, has already been completed at Jochenstein, but the first of the purely Austrian schemes is at present under construction at the Ybbs-Persenbeug site, about half-way between Linz and Vienna. Work here is due to be completed in 1959, but is of interest at present because the scheme was visited recently by delegates attending the Fifth World Power Conference. In the following description we have attempted to pick out one or two points of special interest in its design and construction.



Flow/duration curve of the Danube at Ybbs-Persenbeug and corresponding curves for head and power output of the scheme. The dotted ordinate shows the assumed design conditions of the scheme

The scheme is a large one, with an installed capacity of about 190MW, and also with navigation locks. It is being built by the Osterreichische Donaukraftwerke A.G., the company responsible for exploitation of the Danube for electrical power. Ybbs-Persenbeug will eventually form one of a "cascade" of fourteen stations, extending over a distance of about 340km, from the existing Jochenstein station, to Hainburg, a few kilometres downstream from Vienna. The total head over this distance is nearly 160m; the expected totals of installed capacity and power output respectively, for all the stations are 1940MW and 12,651 million kWh.

The principal data for the Ybbs-Persenbeug scheme are grouped together in the accompanying table. Also, the first illustration shows the design curves for river flow, head and power output. There is no storage, and the barrage will serve solely to create the head. Layout of the scheme was dominated by hydraulic considerations, since a swift stream has to be catered for, and was determined from model tests. It was decided that the flood sluices should be kept in the centre of the stream, to give the best hydraulic layout. So the main generating plant is in two power stations, on the left and right banks respectively. There are to be three 32MW Kaplan turbo-alternator sets in each station, with five flood openings, closed by lowering crest gates, between the two stations. The two navigation locks are on the left bank, inshore of the left bank power station. The approaches to the locks are separated from the main stream by guide walls, extending several hundred metres upstream and downstream from the barrage, giving approach channels 100m in width.

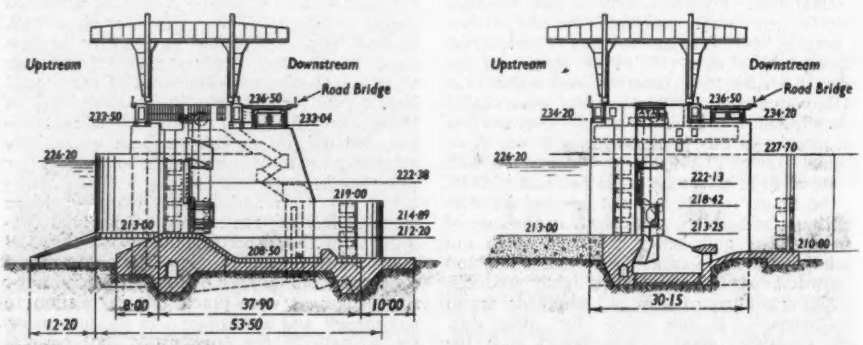
Principal Data for the Ybbs-Persenbeug Hydro-Electric Scheme

Power Station:	
Estimated annual output	1274kWh × 10⁶
Percentage of total output generated in summer	56·8 per cent
Turbo-generator sets installed (number)	6
Capacity of each	32MW
Range of gross heads	6m to 14m
Rated flow, per turbine	350 cumecs
Diameter of turbine runner	7·4m
Turbine runaway speed	178 r.p.m.
Generating conditions	68·2 r.p.m., 50 c/s, 10·3kV
Transmission voltage	220kV
Barrage:	
Number of openings	5
Width of each opening	30m
Width of each pier	7·5m
Height of pair of lowering crest gates	13·5m
Capacity of portal cranes serving barrage and power stations	130 tonnes
Number of portal cranes	2
Width of road bridge spanning barrage	10·7m
Locks:	
Number of locks	2
Useful length of locks	230m
Useful breadth of locks	24m
Filling time	13 minutes
Volume change	60 to 80,000 cubic metres

Lowering Crest Gates.—The barrage and the upstream end of the locks are shown in cross section in the second illustration. It will be seen that lowering crest gates are used in both cases. Such gates were introduced only a few years ago and seem to be gaining rapid acceptance for schemes of this kind in Continental countries. They were first mentioned in this journal in the description of the Birsfelden scheme in Switzerland (THE ENGINEER, June 11, 1954), but since their use on the lock at Ybbs-Persenbeug is of special interest, a brief description is included again here.

Each opening is closed by a pair of gates, both gates spanning right across, the span in this case being 30m, and the depth of water impounded by the gates 13·5m. The lower gate is formed as a box-beam, of substantial cross section, and is carried on wheels at each side. The upper gate is relatively slender and comprises a hook-shaped upper element, over which flood water can discharge clear of the gates, and the flat structure of the gate itself below. The bottom of this gate rests on the lower gate, over which it can slide; thus structurally the upper gate spans in a vertical direction between the "hook" at the top and the lower gate below, and the "hook" shape has a dual function—as a beam, spanning longitudinally, and as a device for throwing flood discharge clear of the structure. The "hook" beam is carried on wheels, as the sketch shows. Clearly, with the triangular load distribution characteristic of an impounding structure, advantage is achieved by the division into two gates, for the upper one is relatively lightly loaded and can be dimensioned accordingly. Furthermore, this advantage brings additional operational merit to the design. The gates can be adjusted, either by lowering the top one or by raising the lower one, and when the two are closed together, they can be lifted clear of the stream. With the comparative lightness of the upper gate, it can be arranged to lower very quickly, and this behaviour can be utilised, with appropriate control mechanism, so that if the flow through the power station is reduced suddenly, instantaneous lowering of one or more of these gates can be arranged, so as to keep the same flow of water in the river.

The right-hand cross section of our illustration shows an alternative use for these gates—they form the upstream gates of the lock. The downstream gates are conventional mitre gates. The interest of the upstream arrangement will be apparent from the illustration. When a vessel is in the lock, and the lock water is at tail-race level, water is introduced by raising the lower of the upstream pair of gates. It will be seen that the lower edge of this gate is shaped like a quarter circle and there is a channel below it, passing to a stilling chamber in the floor of the lock. The shape of the gate bottom directs part of the incoming water into this channel, and hence into the bottom of the stilling chamber. The rest of the incoming water flows straight across the sill of the lock to the stilling chamber, and here the two flows impinge, and their potential energy is dissipated, thus giving smooth conditions in the lock. This stilling device was designed from model tests, and was first used on the Jochenstein scheme. It results in an upward force being imposed on the gate when it is "cracked" open, and so control cables, passing over pulleys in the bases of the lock walls, have been included, to hold the gate down while the lock fills. The use of concrete for the lower gate, to increase its weight, is being considered for the next of the Danube schemes. When the lock is filled to the head-race level, the upper hook-shaped gate is lowered, thus providing sufficient depth of water for vessels to proceed upstream. During catastrophic flood, 25 per cent of the floodwater, it is stated, can be passed through the locks.



Typical cross sections showing (left) lowering crest gates of the barrage and (right) arrangement at upstream gates of lock

The right bank power-house is shown under construction inside its cofferdam, in the foreground. The cellular cofferdam inside which the third and fourth river piers will be built may be noted, and in the background the various works for the construction of the locks

Cofferdams and River Works.—Two main problems present themselves in run-of-river schemes on large rivers, namely, to control and pass effectively floods when the scheme is complete, and to devise a workable sequence of cofferdams during the construction period with the river reasonably unimpeded. Both of these problems were studied with hydraulic models of the site, and, as we have already remarked, the former was solved by proposing a central barrage with power stations on each bank. The velocity of the Danube at Ybbs–Persenbeug is normally 3m to 4m per second, but rises to 7m per second when the river is in flood.

Three main stages of construction are involved in building the river works. The right bank power station is formed largely by widening the river, and so it was enclosed, in the first stage of work, by building a large gravity cofferdam (consisting of a double row of steel sheet piling with filling material enclosed between the rows), extending upstream to a point on the existing river bank clear of the head-race of the right bank station, and downstream, to a corresponding point clear of the tail-race. A similar area was enclosed on the left bank to dewater the site of the two locks.

When the work was sufficiently far advanced in the right bank cofferdam, it was extended into the stream to enclose the area where the first two river piers of the barrage would be situated. These two piers were then constructed up to a level clear of the river, and all the works below river level completed.

It may be recalled that there are four river piers in the complete barrage, with, in addition, a long pier on each side where the barrage joins the power station structure. Having built the first two piers from the right bank enclosure, this enclosure was then modified again, so that the cofferdam aligned itself with the long pier between the barrage and power station, leaving the two completed bays free for the river to flow through them.

An "island" cofferdam was then built, extending from the second river pier and enclosing the area of the remaining two river piers. It consists of a number of contiguous circular cells of steel sheet piling, each cell filled, and with grouting or concreting carried out around the bases of the piles as necessary. A steel crib was placed in the river to drive the piles forming each cell. The floating plant employed included a crane of 200 tons capacity, formerly used for constructing the post-war bridges across the Rhine in Germany. At present work is proceeding inside the cover of this "island" cofferdam, and it is shown in both the photographs reproduced with this article. A good idea of the large areas enclosed by the cofferdams on each bank, where work is also still in progress, is given by these illustrations.

When the two river piers have been built up, inside the island dam, it will be removed, and the third stage cofferdam, also a cellular structure, will be built between the fourth river pier and the outer wall of the locks, on the left bank side. The left bank cofferdam enclosing the locks will, at this stage, have been completely removed, after having undergone several modifications to keep in phase with the three main stages. As the work progresses, the long pier between the barrage and the left bank power station will be built, and the third stage cofferdam will then be reduced in size to align with that pier, leaving the barrage completely free. Thus, in the third stage, impounding will be feasible, and power will be generated in the right bank station, while the left bank station is still under construction.

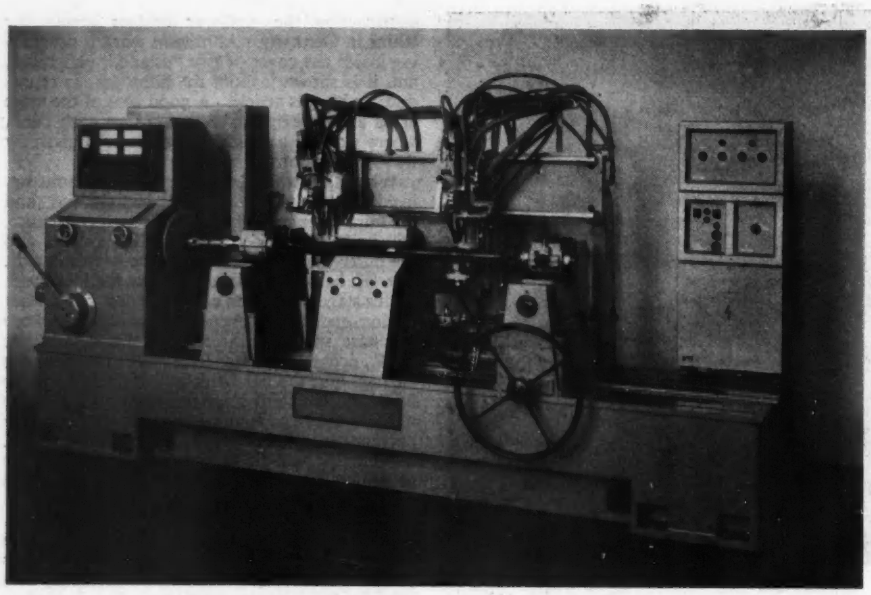
Prestressing the Outer Lock Wall.—The lock walls are of massive construction, the wall between the two locks being 10·5m in thickness and the outer wall 12·5m. Construction was complicated here by earlier work. A hydro-electric scheme had been proposed on the same site before the war, and had reached the stage where a cofferdam had been built. This cofferdam was about ten years old when the work restarted, but was in good shape, and was made use of again. However, it was positioned close to the line of the outer edge of the lock wall, and left too little clearance. Construction of the lock wall in this area had thus to proceed with great care, as the excavation extended rather deeply very close to the cofferdam, which had to be strutted across the excavation.

There was also another problem to be faced. With the left bank power station under construction in the third stage of work, there would be no hydrostatic load on the outer side of the wall, and an appreciable one on the inner side, when the lock was full. These conditions necessitated tying the wall back into the massive lock construction. It should be explained that the inverts of the locks are at a level of 210m and their top water level is 226m, whereas the power station substructure extends down to about 195m, and the outer lock wall to 197m. Thus the outer wall was stabilised by prestressing with cables passing through the concrete of the lock invert and anchored on the inner side of the wall between the two locks. The cables were looped in ducts in the outer wall, and stressed from the central wall; a force of 6000 tons in a length of 25m was thus applied to tie in the wall. The cables were not grouted in the normal manner. Expansion joints have been built between the invert and the walls of the lock. Thus, with normal construction, the movement expected at an expansion joint would also have been experienced by the prestressing cables, and would have been concentrated in a length of only 2cm or 3cm of each cable, and would have been sufficient to break it. Over these critical lengths, therefore, a special form of construction was devised. The cable was encased in a "core" of grout 20cm in diameter, but this core was separated from the surrounding structure by a bituminous sheath, which allowed relative movement between the two.

Construction of the mass concrete walls of the locks of the scheme is here shown in progress, looking upstream, with the cellular cofferdam and the right bank works in the background

Swiss Mechanical Engineering Industry

The upward trend in the Swiss metal producing and engineering industries, which began in the second half of last year, is continuing at a satisfactory rate. Employment in these industries during 1955 increased by 8000, and shortages, both of skilled and unskilled personnel, are being felt. Orders in hand at the end of the year were reported to be enough to ensure full employment for nearly eight months. Last year's machinery exports amounted to 1681 million Swiss francs, compared with 1492 million in 1954, and represented some 30 per cent of the export total. Both for exports and imports the most important country was Germany, with France next, then Italy, the United States of America, and Great Britain.



Balancing machine for cardan shafts, with automatic phase location of unbalance and spot welding equipment for attaching sheet metal weights

Balancing Machine for Cardan Shafts

THE balancing of cardan shafts requires machines specially designed in order to meet the particular conditions of this problem.

Unlike the conventional rotors, cardan shafts cannot run on ordinary plain or roller bearings. Unless articulated in the middle, they are assembled for the purpose of balancing at either end to spindles running on high-precision ball bearings. Shafts with an additional joint in the middle need a third intermediate pedestal.

Because cardan shafts are to some extent flexible, the working speed should be infinitely variable over a wide range. Damage to the cardan shaft at high speed is prevented by a special flexible design of the suspension of the spindles. The smallness of the radius at the points where the unbalance is to be compensated necessitates an exact placing of the balancing weights found in either correction plane. Should an accurate balancing be of importance, an automatic system will lock fast the cardan shaft with the location of the compensation weight just vertically above the axis. This is done for either correction plane in succession.

For large series it is desirable to have spot welding equipment attached to the machine, by means of which the operator can weld sheet metal plates, classified according to weight and bent to the outer radius of the shaft, without taking the cardan shaft from the machine. In the above illustration there is shown a balancing machine built to these requirements by Carl Schenck G.m.b.H., Darmstadt. An electric motor drives the cardan shaft to be balanced through an infinitely variable transmission and an extensible driving shaft. The shaft is assembled at either end to spindles carried elastically on adjustable pedestals. If unbalance is present, the shaft will oscillate normally to the axis of rotation. The horizontal component of these vibrations is used to measure the amount of unbalance. The freedom to oscillate vertically avoids additional stresses in the shaft to be balanced which would inevitably appear at high rotating speed with bearings oscillating in horizontal direction only. The spindles are manufactured with great precision, the admissible radial clearance being only a few thousandths of a millimetre.

The measuring head placed on the casing of the driving unit is equipped in addition to an electric tachometer with four wattmeters, the deflecting coils of which are fed by alternating currents produced by two pairs of vibration pick-ups fastened to the rear of the pedestals.

Two phase generators provide the goniometric currents for the respective field coils. Both left-hand wattmeters are for the left-hand pedestal, the right-hand meters for the right-hand one.

Thus each side has its separate phase generator supplying its two wattmeters with goniometric currents in quadrature to one another. Both phase generators run at the same rotating speed as the cardan shaft to be balanced, hence the alternations of the currents produced are synchronous with the respective components of the unbalance vibration. The wattmeter readings are proportional to the product of the intensity of the goniometric current and the " in-phase " component of the pick-up voltage. For this reason the vibrations indicated are due to the unbalance exclusively, and parasitic vibrations of alien frequencies as well as higher harmonic vibrations are screened off automatically.

In order to determine the angular location of the unbalance, the body of either phase generator can be displaced angularly by manual operation of a handwheel. The two handwheels are arranged on the front side of the driving unit casing. With the machine running, the reading of the upper wattmeter at the respective side is reduced to zero by operation of the corresponding handwheel. The lower wattmeter of the same pair then displays the maximum deflection of the pointer because the two goniometric currents are, as mentioned above, in quadrature to one another.

A search commutator, adjusted simultaneously with the phase generator, locks the cardan shaft in such a way that the unbalance is just above the axis of rotation. An indicator light shows whether the angular position thus found concerns the left-hand or the right-hand end.

After a suitable sheet weight has been spot welded at the indicated position, the cardan shaft is released by the operation of a push button and turned by hand until the second lock would catch. In the new position thus achieved a sheet metal weight is likewise spot welded at the other end. The welding jaws are closed by compressed air. The ball bearings of the spindles are kept isolated from the welding current, which would otherwise destroy them. A water-cooling system prevents an overheating of the studs and cables.

The timing of the welding process and the intensity of the welding current are adjustable and kept constant automatically by a control unit at the right-hand side of the machine base.

The sole agent in the United Kingdom and Commonwealth is W. and T. Avery, Ltd., Soho Foundry, Birmingham, 40.

West German Shipbuilding

Deliveries by shipyards in the German Federal Republic last year amounted to 320 new ships totalling 890,061 gross register tons (1954, 256 ships and 893,536 gross register tons). In terms of tonnage, the figures therefore tend to stabilise within the limits of present building capacity, although the money value of the ships increased slightly over 1954. A certain trend away from tankers and towards ships with a higher amount of fitting-out was noted. Tanker construction amounted to twenty-three ships and 290,000 gross register tons, or 48 per cent of the total. About 31 per cent of the ships were steam driven, the others being motorships. Just under one-half (48·5 per cent) of the ships built were for foreign owners.

Inland shipping construction amounted to 200 ships totalling 133,157 tons, as compared with 123 ships and 81,728 tons in the preceding year. Of the deliveries, forty-one ships totalling 23,606 tons were for abroad (in 1954 these figures were twenty-five ships and 7962 tons). Motor freighters numbered 135 (96,760 tons), motor tankers twenty-nine (23,182 tons) and barges thirty-six (13,215 tons).

New orders at the beginning of this year stood at 589 ships (2,690,000 gross register tons), as compared with 433 ships and 1,590,000 gross register tons at the beginning of 1955. Nearly 64 per cent are foreign orders, compared with 54·7 per cent in 1954. Tankers account for 25 per cent, i.e. forty ships of 590,000 gross register tons, of which thirteen ships of 186,000 gross register tons are for the German Federal Republic and twenty-seven tankers with 404,000 gross register tons for abroad. Thirty per cent, compared with 27 per cent last year, are to be steam powered.

Orders for inland ships have reached the highest level since 1945. At the beginning of 1956 there were 298 ships on the order books, amounting to nearly 260,000 gross register tons, compared with 159 ships and 140,000 tons a year earlier. Of these, eighty-eight ships with together 8500 tons are for foreign owners, compared with twenty-six ships and 30,500 tons in the year last but one.

The value of last year's production was DM. 1750 million (DM. 1660 million in 1954). Repairs reached 17·2 per cent of the total turnover (17·5 per cent in 1954). These figures do not include assemblies or separate components.

Lake Constance Water Supply Scheme

Work has begun on a water conduit linking Lake Uberlingen (the north-westerly tip of Lake Constance) with seventeen towns in Württemberg, including Stuttgart, Ludwigsburg, Tübingen, Böblingen and Reutlingen. The conduit will be over 100 miles long and the total cost of the project, which is to be completed in two years, will be about DM.170 million.

The plan to provide the industrial area of central Württemberg with water from Lake Constance is almost half a century old, and four schemes for its realisation were considered and rejected before the present plan was conceived. Since the end of the last century, the population in the area has nearly trebled, and industry has greatly expanded. In consequence, during periods of drought in recent years the water supply has had repeatedly to be reduced. With an additional supply of the order of 90,000,000 cubic metres per annum from Lake Constance, it is thought that requirements can be met for the next twenty-five years when the density of population in the Stuttgart region is expected to rise to 800 persons per square kilometre.

Erection of Broad-Strip Rolling Mill

According to an announcement made at its recent annual meeting, Hahnsche Werke A.G., Duisburg-Grossenbaum, is to begin the construction of a new broad-strip rolling mill, which is to come into operation towards the end of 1957. The additional capacity will increase the monthly output of broad strip from 8000 to 12,000 tons. The present broad-strip mill is for widths of 150mm to 1250mm. Working in three shifts, it has recently exceeded for the first time an output figure of 200,000 tons. The new strip mill is to roll to widths of 150mm to 800mm.

System of Louvres for Fish Collection

BY OUR AMERICAN EDITOR

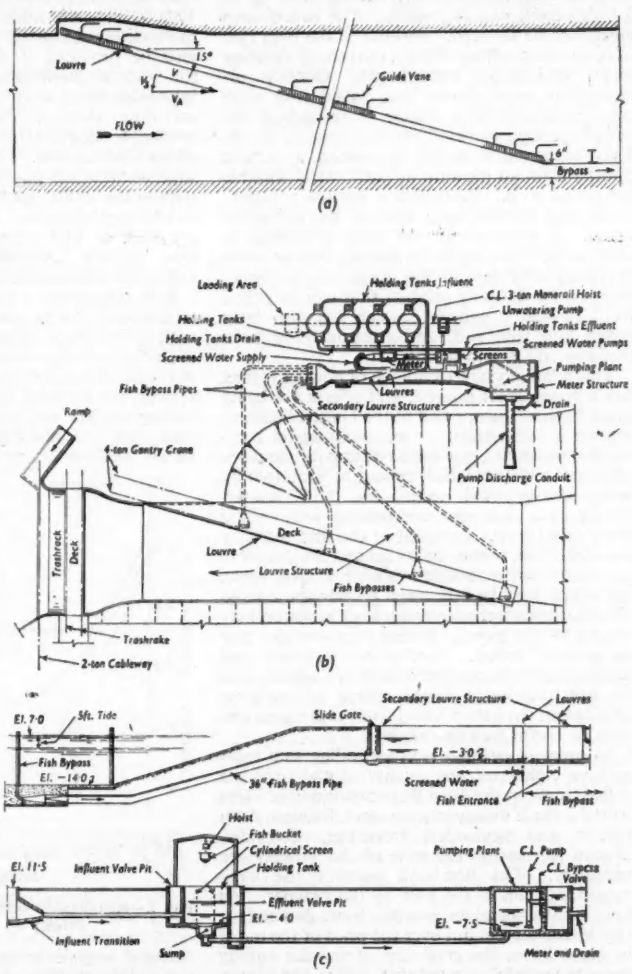
AN interesting system of fish collecting facilities is under construction at the intake to the Delta-Mendota Canal, a principal irrigation artery on the Central Valley Project of the Bureau of Reclamation in California. When completed these facilities will prevent millions of young fish, mostly salmon, bass, shad, and catfish, as small as ½in in length, from entering the canal at its intake in the Delta area of the project. In brief, the facilities divert the fish from the main flow of water by means of a row of vertical louvre vanes set 1in apart and directed at right angles to the flow in a structure which extends about 340ft diagonally across a concrete channel 83ft 6in wide and about 25ft deep. As the fish approach the louvres they swim to one side to avoid the disturbing eddies and vibrations created by the louvres, and readily enter by-passes placed at intervals in the louvred barrier. The by-passes carry the fish to holding tanks. From the holding tanks the fish are to be transported by lorries 40 miles to the Suisun Bay area where they can swim safely to the ocean.

The Delta region is a maze of tidal channels at the head of San Francisco Bay. The Delta Cross Channel carries surplus Sacramento River water from the northern end to the southern end of the Delta for delivery to the intake of the Delta-Mendota Canal. Water from the intake is then conveyed 2½ miles to the Tracy Pumping Plant, which lifts the water 197ft into the canal for delivery to irrigable lands 120 miles to the south. The fish collecting facilities are being built adjacent to the Old River, which serves as a natural link in the Cross Channel.

The Delta area is the most important spawning and rearing region for striped bass and shad on the Pacific coast. Young king salmon are found in great numbers in the waters of the Delta where they loiter on their way to the ocean. Catfish are an important sport fish that spend their life cycle in the Delta waters. Salmon, bass, and shad are anadromous fish—they spawn in fresh water but spend their adult lives in the ocean. The young fish descend the rivers to the ocean, carried by and following the major flows of water. During periods of low flow in the Old River and when the canal is operated at capacity, the Tracy pumps will take all of the flow of the San Joaquin River entering the Delta from the south and may draw half of the Sacramento River flow. Thus, the major diversion of the Delta-Mendota Canal operating at full capacity would be nearly as great an attraction to these young fish as would the combined river flow of the Sacramento and San Joaquin rivers to the ocean.

The principle of the louvre scheme is shown at (*a*). The fish are carried tail first by the approach flow until they "sense" the disturbance created by the louvres. They then orient themselves approximately normal to the line of louvres and swim to avoid the disturbance. The swimming velocity, V_s, together with the approach velocity, V_a, in the channel produces the resultant velocity, V, with which the fish move along the line of louvres and into the by-pass. Experiments have shown that the louvres will divert over 90 per cent of the fish into by-passes and that the louvres are particularly effective in maintaining a low mortality rate because there is no physical contact with the fish and the fish are not exhausted by their swimming efforts.

During a large part of the diversion period there is considerable peat moss in the Delta waters and it is carried to the canal intake by the pumping draft of the Tracy pumping plant. The moss ranges from small particles more or less evenly distributed in the water to large floating or semi-floating islands. When the fish are collected for hauling, the concentration of moss in the water must be considerably reduced to prevent suffocation of the fish. A plan of the facilities is shown at (*b*), and a section through the structure along the path of the fish is shown at (*c*). Fish entering the louvre structure are deflected by louvres into by-passes. The by-passes are connected with by-pass pipes situated beneath the structure. The by-pass pipes carry the fish to a secondary louvre structure where a double line of louvres is used to concentrate the fish further and to separate them from the moss-laden water. Screened water is introduced at the side of the secondary louvre channel just ahead of the by-pass in such a way that the clean water flows alongside the mossy water and enters the by-pass instead of the mossy water. Fish traversing a line of louvres will cross over into the screened water and enter the by-pass along with the clean water.



(*a*) Diagram showing principle of fish-collecting louvre scheme. (*b*) Plan view of fish collecting facilities. (*c*) Sectional view of fish-collecting facilities

From the secondary louvre by-pass the fish are carried in a pipe to one of four holding tanks. Flow entering a holding tank will be about 10 cusecs when the maximum flow of 4600 cusecs is directed into the Delta-Mendota Canal. Fish are held in the holding tank by an 8ft diameter cylindrical wire mesh screen placed on the vertical centre line of the tank. Water passes through the screen and leaves the tank at a sump in the bottom of the tank. When the fish are to be transferred from a holding tank to a hauling lorry, the by-pass flow is routed to another tank and the tank containing the fish is drained by the sump pumps of all but 500 gallons of water and fish. A 500 gallon capacity bucket is lowered through the cylindrical screen and into the holding tank sump, the screen is raised, and the fish and water are deposited into the bucket. The bucket is then raised and the fish transferred to a refrigerator lorry which hauls them to the Suisun Bay area beyond the influence of the diversion to the canal.

The water surface in the main louvre structure, the secondary louvre structure and the holding tanks fluctuates with the tide. The difference in water levels required to move water through the collecting facilities is produced by a pumping plant which has one set of pumps for holding tank flow and another set for secondary louvre structure flow. The quantity of water pumped through the facilities is regulated by the number of pumps in operation and by recirculating flow through by-pass valves. The velocity of flow in the main louvre structure will vary about 1ft per second because of tidal action. Experiments show that the velocity of water entering the fish by-passes should be greater than the velocity of the approach flow, but probably can exceed the approach flow velocity by as much as 2·5ft per second. Therefore, the flow through the collecting facilities can remain constant for any particular number of pumps in operation at the Tracy pumping plant.

A trashrack having 2in clear spacing between bars protects the louvre structure. Small debris collecting on the rack is removed by a mechanical rake and large debris is hauled by means of a cableway to the end of the trashrack where a ramp is provided for removal of debris. Louvres are divided into panels and a gantry crane is provided on the operating deck to lift the panels so that fine debris collecting on the louvres can be washed off with water from a high pressure hose.

The design of the present facilities was developed from studies conducted at a pilot structure. Incorporated in the experimental structure were stationary screens of wire mesh and perforated plates, conventional travelling water screens, a system of ports and risers for by-passing fish, and a fish-holding pond. In the spring of 1952, when the temporary structure was taken into operation, it soon became evident that it would be impossible to keep the stationary screens free of debris, and some of the stationary screens were later replaced with travelling screens. As the fish did not enter the by-pass ports as expected, they were removed from the water by forcing them with high screening velocity against the travelling screens so that they could be lifted bodily from the water along with moss and trash in trays on the screens. A small test flume was constructed at the pilot structure, and experiments were conducted with filtered water. During this test period the advantages of using a line of louvres to deflect fish into a by-pass were realised. Further studies were made on a larger experimental flume, constructed in one of the bays of the pilot structure. Flow straightening vanes were developed for the louvres by the Hydraulic Laboratory of the Bureau of Reclamation. Many tests were made in the flumes to determine the spacing of the louvre slats, approach velocity limitations, and the best angle for the line of louvres. As shown at (*a*), the maximum approach velocity is a function of the swimming ability of the fish and the louvre angle. Theoretically, fish having

a normal continuous swimming ability of 1ft per second will traverse an approach velocity of about 4ft per second with a louvre angle of 15 deg. Tests showed that for a given swimming speed and flow the required area along the line of louvres is the same regardless of the angle. The experimental studies and development of the louvres for the fish collecting facilities were conducted as a joint effort of the Bureau's regional office at Sacramento, the U.S. Fish and Wildlife Service, and the California State Fish and Game Department. The designs and specifications for the facilities were prepared in the Denver offices of the Bureau under the general direction of L. N. McClellan, Assistant Commissioner and Chief Engineer.

Roll Compacting of Powdered Metals

IN presenting the 1955 Gillett Memorial Lecture to the American Society for Testing Materials, Professor F. V. Lenel, of the Rensselaer Polytechnic Institute, recently stressed the important future awaiting the powder rolling technique, as part of general powder metallurgical fabrication practice. In accordance with well-established current methods, most semi-fabricated powder products are to-day produced by a hot working process : extrusion, forging, or hot pressing. In the conventional sequence of powder metallurgy operations, the forming step, which is compacting, is done at room temperature. The question arises whether this room temperature compacting step could not be modified so that semi-fabricated products could be produced directly from powder. This question was answered affirmatively by German investigators, who studied the rolling of iron powder into strip, while later laboratory studies of powder rolling were made in England on copper powder and in America on stainless steel powder.

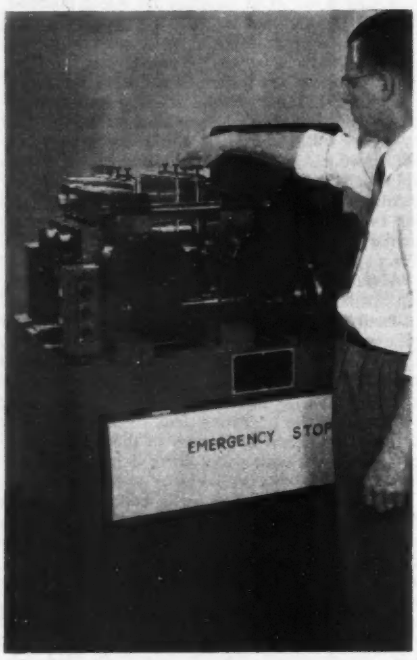


Fig. 1—6in by 6in "Stanat" horizontal powder metal rolling mill

The rolls of the rolling mill, in which the powders are rolled, may be arranged above each other as in conventional rolling practice, or they may be in a horizontal plane. The powder is fed into the gap between the rolls. The friction between the rolls and the powder pulls the powder into the gap where it is compacted ; it emerges as a continuous strip. Varying the gap or clearance between the rolls will produce variation in the pressure applied to the powder and therefore in the density of the strip. A narrow roll gap is required for producing dense strip. Some control over the thickness of the strip is possible by controlling the amount of powder fed into the roll gap. The surface finish and speed of the rolls and particle size and shape of the powder also have some influence upon the density and thickness of the strip. The maximum thickness of high-density strip that can be rolled from a given powder depends, however, primarily upon the diameter of the rolls. For iron or stainless steel powder, 8in diameter rolls will produce strip up to 0·040in thick, whereas 36in diameter rolls will produce strip up to 0·180in thick. Copper powder, on the other hand, because it is softer and more easily deformed, will produce thinner strip ; with 8in diameter rolls high-density strip up to 0·025in thick can be rolled. The rolled strip must then be sintered. Because of the high rate of continuous rolling of strip, the rate of sintering must be adjusted accordingly. German investigators have shown that rolled iron strip can be sintered in a matter of seconds if the sintering temperature is 2200 deg. Fah. and above. They suggested sintering by passing a current directly through the strip as particularly suitable for rolled strip. Even with a narrow roll gap, rolled and sintered strip will not be completely dense. If a strip with the same properties as strip rolled from ingots is desired, one or more re-rolling and re-sintering steps are required. Strip is not the only product that can be rolled from powder ; copper powder has also been rolled into wire rod, and attempts have been made to roll it into tubing.

This relatively new technique of powder rolling has aroused great interest, and efforts are being made both in Europe and in the United States to exploit it commercially. In assessing its commercial feasibility, one has to distinguish between rolling of products which cannot be produced by more conventional techniques, and powder rolling as a technique competitive with rolling from cast ingots. Included in the first category are alloys that cannot be rolled and are therefore at present not otherwise available in strip form, but which may be fabricated by powder rolling. Transformer sheet alloys very high in silicon may belong to this group. Porous strip or sheet may be powder rolled. Studies on stainless steel strip made from powder appear to indicate that its structure has a lower degree of preferred orientation than strip rolled from cast ingots and may be useful for this reason.

In order to evaluate powder rolling as a competitive technique, the quality of the products rolled from powder must first be considered. This would include dimensional control, freedom from defects, and mechanical properties. Secondly, precise figures for the cost of the process are necessary. The first and possibly the most important item is the cost of the powder. As long as the metal in powder form demands a considerable premium over the price of the metal in ingot form, the economy of powder rolling appears doubtful. For copper, nickel, and cobalt, hydro-metallurgical methods of producing the metals from ore or scrap have been developed in which the metals are obtained in powder form. Combining this lower-cost method of making powder with the powder rolling technique for producing thin-gauge copper strip for such applications as automobile radiators is now being investigated in America. Certain metals are produced from their ores not in the form of massive metals but as sponge—for instance, titanium and zirconium. Melting the sponge into ingots is relatively expensive, but the sponge can be readily crushed into powder. The suggestion has therefore been made to apply powder rolling to titanium and zirconium. An experimental powder metal rolling mill is now being installed at the Experimental Station of E. I. duPont de Nemours and Co., the major American producer of titanium sponge.

Besides the cost of the raw material, the other items of cost—the actual rolling of the powder, sintering, re-rolling, and annealing—must be considered in a cost analysis. Fewer passes should be necessary to roll strip from powder to the desired gauge. On the other hand, the techniques of rolling strip from ingot have been made highly automatic and therefore relatively low in cost. Thus, a reasonable commercial future can be expected to exist only for those metals that do not lend themselves readily to processing by the conventional ingot-to-strip fabrication sequences.

The growing interest in metal powder rolling techniques recently led to the development of a new experimental powder metal rolling mill by the Stanat Manufacturing Company, of Long Island City, New York. The machine, which is shown in Fig. 1, has 6in diameter by 6in face width chromium-vanadium alloy steel cold rolls, arranged horizontally, which turn on cage type needle roller bearings ; end thrust is taken by radial ball bearings. Designed to withstand great compacting pressures, each roll neck bearing has a load capacity of 50,000 lb, equal to a maximum roll separating force capacity of 100,000 lb. An additional set of chromium-molybdenum-tungsten alloy steel hot rolls may also be provided if the mill application calls for work at elevated temperatures. To obtain internal heating, such hot rolls may be fitted with cartridge elements, including sliprings and brushes to feed electric current to the cartridges, which heat the rolls. For processing applications, such as titanium powder, it is also possible to enclose the entire machine in a vacuum or inert atmosphere chamber. The two mill housings are cast of high-strength "Meehanite" alloy iron, and the cross-sectional area of the four mill posts is 48 square inches.

Roll adjustment is made by means of a single handwheel, worm gear screwdown provided with lifting studs which permit positive control of the roll setting in either direction. A graduated dial provides micrometer adjustment of the roll setting, and a clutch is provided to aid in establishing perfect roll parallelism. The machine base and roll housing mounting plate are of welded steel construction with provision to permit material to pass beneath the rolls and through an independently installed sintering furnace. Close control of the resulting strip widths is obtained by a set of precisely machined stainless steel side guides. The mill is powered by a 5 h.p., four-speed gearshift drive designed to operate at speeds of 10/20/30/40 r.p.m. It is controlled by forward and reversing magnetic starters with overload protection actuated by remote control push button stations. Emergency stop panels are situated on the front and the rear of the machine and ensure fast stopping by the use of an electromagnetic brake on the motor. In recent performance tests, the mill illustrated successfully produced strip from such powders as copper, brass, nickel, nickel-silver, aluminium, molybdenum, tantalum, stainless steel and other ferrous alloys.

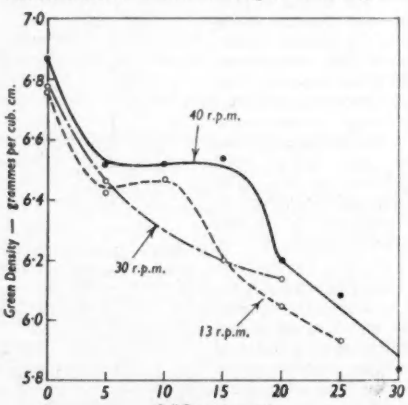


Fig. 2—Relationship between roll opening and green density of strip produced

Once the feasibility of rolling soft metal powders had been established, the question naturally arose as to whether harder powders could be treated similarly, and, further, what

properties could be expected from the resulting products. Since 18–8 stainless steel has a wide variety of industrial applications, the Atomic Energy Division of Sylvania Electric Products, Incorporated, of Bayside, New York, selected this material for study. This firm's work was aimed at determining how strip rolled from 18–8 steel would compare with strip obtained by the usual industrial methods and by the conventional powder metallurgy technique of die pressing and sintering.

The rolling and densifying of 18–8 stainless steel powder into strip was performed on the rolling mill shown in Fig. 1. The powder is fed by hand or from a hopper into the 6in diameter rolls of the mill. The resultant green, compacted strip is then sintered in a hydrogen atmosphere. Some of the as-sintered specimens are then re-rolled and annealed.

Fig. 2 represents the relationship between the density of the strips produced and the roll opening. The non-uniformity of the curves obtained for roll speeds of 13, 30 and 40 r.p.m. is believed to have been caused by the type of powder feed used. The experimental results indicate that narrow roll openings and fast roll speeds are required to produce high-density strips; in fact, the thickness of the strips increased linearly from approximately 32 to 50 mils as roll openings were increased from zero to 30 mils (1 mil=0·001in).

A study was made of the effect of sintering temperature on the density of green strips rolled under conditions of zero roll opening, hopper-fed powder, and a roll speed of 30 r.p.m.; a graphic

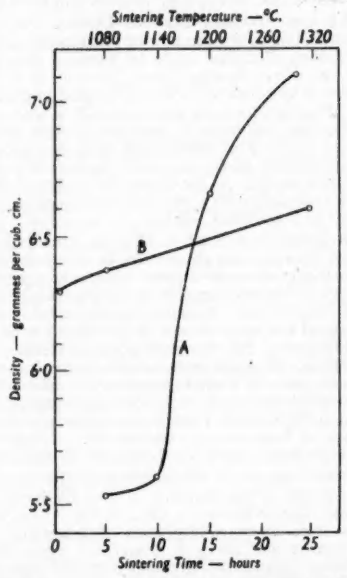


Fig. 3—Relationship between sintering temperature (*A*) and sintering time (*B*) and green density of strip

illustration of the experimental results is shown in Fig. 3 (curve *A*). The specimens were held for twenty-four hours at each of the temperatures indicated, and, as can be seen, the density increased with increasing sintering temperature. At 1300 deg. Cent. a density value of over 90 per cent of theoretical was obtained. The effect of sintering time on density is illustrated by curve *B* of Fig. 3. The specimens used to obtain the data for this curve were sintered at 1200 deg. Cent. It may be seen that even for long sintering times little substantial gain in density is obtained. It was observed that the strip thicknesses did not change to any extent after the sintering operation.

In addition to an increase in density, the ultimate tensile strengths of the strips were likewise improved by sintering. Little strengthening occurs at the low temperatures; however, high strengths are developed at high temperatures and long heating time. Strengths of 90,000 lb per square inch were attained after specimens were held at 1300 deg. Cent. for twenty-four hours. The increase of strength with sintering time is shown in Fig. 4. This effect became more pronounced at higher temperatures.

The elongation of the as-sintered specimen was studied both as a function of the sintering temperature and the time in which the sample was held at temperature. In specimens held for one, five and twenty-four hours at temperature, it was observed that only at high temperatures and for long holding times did appreciable sintering and increase in elongation occur. Elongations as high as 20 per cent were developed after sintering at 1300 deg. Cent. for twenty-four hours. Very little change occurred in the specimens held for one hour at temperature, regardless of the temperature used. Fig. 5 is a plot of elongation versus sintering time. It appears that relatively little change in elongation occurs regardless of the time during which the sample is held at either 1080 deg. or 1140 deg. Cent.; however, marked increases in elongation with increasing sintering time can be seen at the isotherms 1200 deg. and 1300 deg. Cent., especially at the latter temperature.

The specimens were re-rolled cold in order to densify and further strengthen the as-sintered

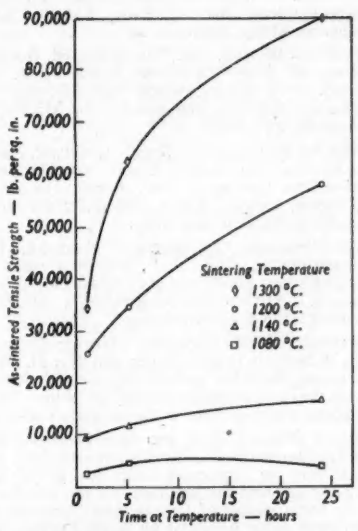


Fig. 4—Relationship between sintering time and ultimate tensile strength of strip as sintered

strip. In a number of instances this was followed by annealing of the strip, and then by further cold rolling. The density of such strip was 7·83 grammes per cubic centimetre as compared with 7·93 grammes per cubic centimetre for ordinary 18-8 stainless steel. An unetched microstructure showed that the strip was almost fully densified and that none of the original powder particle boundaries were visible. For an etched structure it was observed that a considerable amount of the steel was in the form of martensite in a matrix of austenite. The original particle boundary outlines were visible and some elongation of the particles in the direction in rolling was evident. Martensite is present because the austenite of 18-8 stainless steel is of a non-equilibrium condition and can be converted to martensite by cold working the alloy. The more severe the deformation of the austenite the greater is its conversion to martensite. The conversion is also dependent upon the alloy chemical composition and on the temperature of cold reduction, among other variables.

Some additional experiments were conducted to determine the effect of re-rolling on the degree of preferred orientation and corrosion resistance. X-ray spectrometer analyses were made of re-rolled specimens and the degree of preferred orientation was obtained in a qualitative manner. Practically no preferred orientation was obtained for a specimen re-rolled five times. In comparison to 18-8 stainless steel sheet produced in the conventional manner, these powder metallurgy specimens of rolled sheet showed practically no preferred orientation.

The corrosion resistance of strip that was rolled, sintered, and further densified by an additional cold-roll pass was investigated. This included tests on specimens both in the cold-rolled and annealed conditions, as well as a comparison of wrought 18-8 stainless steel strip. Corrosion studies were carried out in water at 680 deg. Fah. for periods up to 1000 hours; the results are tabulated in Table I.

TABLE I—*Corrosion in Water at 680 deg. Fah. Rates in mg/cm² × 10³*

Time held in H_2O, hours	Rolled powder strip		Wrought strip annealed
	Annealed	Cold worked	
25	30	120	50
100	110	160	90
500	290	350	280
1000	360	730	—

Strip in the cold-rolled condition corroded at a more rapid rate than the other materials tested. A comparison was made between wrought 18-8 stainless steel sheet and powder metallurgy sheet, both of which had been annealed and quenched. Little difference in the rates of corrosion of both these specimens was found, indicating that stainless steel sheet made by powder rolling and sheet made in the conventional manner have equal corrosion resistance under the test conditions imposed. In addition to corrosion data, the company found that the maximum ultimate tensile strength of strips re-rolled three times and annealed was 108,000 lb per square inch, and the elongation value was 33 per cent. These results are compared in

TABLE II—*Comparison of Properties of 18–8 Stainless Steel Fabricated by Various Methods*

Material	Ultimate tensile strength, lb per sq. in	Elongation, per cent
Wrought 18-8 stainless steel, annealed	80,000 to 90,000	55–60
Die-pressed, sintered and coined powder metallurgy specimens made from 18-8 stainless steel	87,000	32
Re-rolled powder strip made from 18-8 stainless steel	108,000 (annealed after re-rolling)	33

Table II with steel strip fabricated by other methods.

In addition to the above work in the field of stainless steels, there is much interest

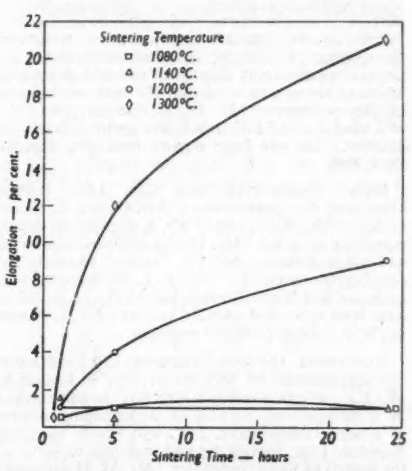


Fig. 5—Relationship between sintering time and elongation of strip in the as-sintered condition

being expressed in the United States in the production of refractory metal strip by means of continuous roll compacting. Such metals as tantalum and molybdenum are finding growing applications in the chemical, electrical and electronic industries, and are often required in relatively long coils of thin strip. In the past, the limitations imposed by powder metal ingot fabricating facilities had severely limited the production of continuous coils of strip, but now there is considerable hope of manufacturing long coils of roll compacted and sintered strip by the methods outlined above.

Personal and Business

Appointments

MR. S. L. POOLE has been appointed production director of Bowden (Engineers), Ltd., Willesden Junction, London, N.W.10.

MR. C. J. HYDE TRUTCH, M.I.C.E., has been appointed managing director of Victory-Kidder Printing Machine Company, Ltd.

BRIGADIER-GENERAL E. G. WACE has been re-elected chairman of the Road Emulsion Association. Earl Temple of Stowe has been elected vice-chairman.

MR. H. W. G. HIGNETT has been appointed assistant managing director of Henry Wiggin and Co., Ltd., Thames House, Millbank, London, S.W.1.

EXPANDITE, Ltd., Chase Road, London, N.W.10, announces the appointment of Mr. A. W. Morrison as technical manager responsible for production and development.

MR. W. R. B. FRANK, A.M.I.Mech.E., 87, Staincross Common, Mapplewell, Barnsley, is taking up an appointment in India with the United Nations Technical Assistance Administration, as a glass production expert.

A.P.V.-PARAMOUNT, Ltd., Manor Royal, Crawley, Sussex, states that Mr. E. J. Cooper has been appointed production superintendent, in succession to Mr. L. J. L. Davies, who has become southern area representative.

HEYES AND CO., Ltd., Wigan, states that Mrs. M. H. Redmond and Mr. R. S. Redmond have been appointed directors. Mr. Norman F. Brand, A.M.I.E.E., and Mr. W. Talbot are in charge of production and the technical side of the business.

ASSOCIATED BRITISH ENGINEERING, Ltd., states that Mr. E. M. Benjamin is taking up special duties with two of the subsidiaries, namely, Henry Meadows, Ltd., and Free Piston Engine Company, Ltd. He will continue to serve on the board of the parent company.

MR. W. JOBLING, technical manager, has been appointed a director of William Doxford and Sons (Shipbuilders), Ltd. Mr. J. A. Hardy, technical manager, and Mr. P. Jackson, research and development manager, have been appointed directors of William Doxford and Sons (Engineers), Ltd.

GEORGE ELLISON, Ltd., Petty Barr, Birmingham, 22B, states that Mr. L. A. Yardley has been appointed as engineer responsible for sales and the consultative service in Lancashire, Yorkshire, Northumberland, Cumberland and Scotland. His address is 1, Central Street, Manchester (telephone, Blackfriars 7637).

THE ENGLISH ELECTRIC COMPANY, Ltd., states that Sir George H. Nelson, Bt., has relinquished his position as managing director in order to devote the whole of his time to the duties of executive chairman of the company. Mr. H. G. Nelson, M.I.C.E., M.I.Mech.E., M.I.E.E., has been appointed managing director. He has been deputy managing director since 1949.

HICK, HARGREAVES AND CO., Ltd., Bolton, announces the appointment of Mr. Gilbert F. Davies as deputy chairman, and of Mr. J. Aspinall as deputy managing director. Mr. Davies will continue to act as London director. Mr. J. L. Leyland, secretary and commercial manager; Mr. J. J. Warburton, sales manager, and Mr. V. Barnett, technical representative, have been appointed special directors. Mr. T. Nuttall has been appointed works manager.

LANCASHIRE DYNAMO HOLDINGS, Ltd., announces the appointment of Mr. R. V. Ely, M.I.Mech.E., M.I.E.E., as group research director. In consequence he is relinquishing his position as managing director of Foster Transformers, Ltd., and Foster Electrical Supplies, Ltd., though he will continue to serve on the boards of those companies. Mr. M. H. Hammill, who is general manager and a director of Foster Transformers, Ltd., will take executive charge of that company, and Mr. L. D. Gunnell, sales director, will act similarly for Foster Electrical Supplies, Ltd.

ASSOCIATED ELECTRICAL INDUSTRIES, Ltd., states that Mr. C. Y. Knight has announced his intention to retire. He will cease to be chairman and a director of Australian Electrical Industries Pty., Ltd., as from September 7th, but will continue as deputy chairman of A.E.I., Ltd., until his departure from Australia towards the end of the year. Major-General Sir Jack Stevens is joining the board of the A.E.I. Group in Australia; he will succeed Viscount Chandos as chairman of the holdings company, A.E.I., Ltd., and Mr. Knight as chairman and chief executive of the operating company, Australian Electrical Industries Pty., Ltd.

Business Announcements

MR. NEILL CHRISTIE has relinquished his appointment as secretary of the Radio and Electronic Engineering Association.

CEMENTATION (MUFFELITE), Ltd., has changed its address to 20, Albert Embankment, London, S.E.11 (telephone, Reliance 6556).

GOODENOUGH PUMPS, Ltd., Twickenham, Middlesex, has opened a N.W. area depot at 129A, Guide-Lane, Audenshaw, Lancs (telephone, Ashton 3875).

WINSTON ELECTRONICS, Ltd., Govett Avenue, Shepperton, Middlesex, states that its telephone number has been changed to Walton-on-Thames 6321.

BRITISH OXYGEN GASES, Ltd., states that the capacity of its works at Brinsworth, Yorks, is being increased by the addition of a second liquid oxygen plant.

THE MINISTER OF HOUSING AND LOCAL GOVERNMENT has approved, in part, the proposal of Commer Cars, Ltd., to build a factory in the Luton–Dunstable neighbourhood.

PRAT-DANIEL (STANMORE), Ltd., Nailsworth, Glos, has moved its Stanmore office to 4, Westminster Palace Gardens, Artillery Row, London, S.W.1 (telephone, Abbey 7661).

LEYLAND MOTORS, Ltd., has purchased, from the Ministry of Supply, a factory at Farington, near Preston. The factory, which was built for tank production, has been managed for the Ministry by Leyland Motors, Ltd.

APPLEBY-FRODINGHAM STEEL COMPANY, Scunthorpe, states that, as from October 1st, The British Steel Piling Company, Ltd., King's House, 10, Haymarket, London, S.W.1, will undertake all the sales of Frodingham steel piling.

THE ELECTRIC CONSTRUCTION COMPANY, Ltd., Wolverhampton, states that its district office for Scotland is now established at 8, Woodlands Terrace, Glasgow, C.3 (telephone, Douglas 1962). Mr. N. R. Wheldon is the district manager.

HACKBRIDGE AND HEWITTIC ELECTRIC COMPANY, Ltd., Walton-on-Thames, states that Mr. H. Fraser has retired from his position as chief of electrical tests in the transformer and rectifier divisions. He has completed thirty-six years in the company's service.

SOUTH DURHAM STEEL AND IRON COMPANY, Ltd., and THE BRITISH STEEL PILING COMPANY, Ltd., have stated that the agreement under which the latter company has held the sole right for the sale for use in the home market of Larssen steel piling and any other steel piling produced by South Durham Steel and Iron Company, Ltd., is to end on September 30th. Thereafter, all inquiries for Larssen steel piling, for the home and export markets, should be addressed to South Durham Steel and Iron Company, Ltd., Middlesbrough.

Contracts

THE ENGLISH ELECTRIC COMPANY has received from the Tennessee Valley Authority orders for three large transformers, to a total value of over £200,000. Two of the transformers (three-phase, outdoor forced-oil-cooled equipments, rated at 170MVA, 17·1/161kV) are for the Johnsonville steam plant; the third (three-phase, 50MVA, 60 c/s, 57/13kV) is for Lenoir City. The transformers will be built at the company's Stafford works.

TAYLOR WOODROW CONSTRUCTION, Ltd., has received a contract, valued at £3,250,000, from the Central Electricity Authority, for the first stage of the civil engineering work for the new power station at High Marnham, Notts. The work on this first stage will take three and a half years. When fully complete the power station will house five English Electric 200MW turbo-generator sets. The consulting engineers are Freeman, Fox and Partners.

SIMON-CARVES, Ltd., Cheadle Heath, Stockport, has received contracts amounting to about £4,500,000 from the Steel Company of Wales, Ltd., for new coke-oven construction in connection with the recently announced development programme at the Margam works. Under these contracts two existing batteries of ninety coke ovens will each be extended by the addition of twenty-five new ovens, and a complete new battery of eighty ovens, together with by-product plant and coal and coke handling equipment, will be built on a new adjacent site.

THE STANTON IRONWORKS COMPANY, Ltd., has secured a contract from the River Dove Water Board covering the supply of approximately 11,200 yards of 42in diameter, approximately 400 yards of 36in diameter and approximately 1500 yards of 30in diameter prestressed concrete pressure pipes and "specials" with lock joints, and approximately 1500 yards of 30in diameter spun reinforced concrete pipes and "specials" with Stanton-Cornelius joints. These pipes are to form the raw water aqueduct which will run across country from the River Dove intake at Stretton, near Burton-on-Trent, via Repton and Ticknall, to a reservoir to be constructed at Staunton Harold, near Melbourne, on the Leicestershire-Derbyshire border. The construction of this pipeline forms part of the first stage of a scheme to provide additional water supplies to the Leicester Corporation, Loughborough Corporation and other constituent authorities in both Leicestershire and Rutland, with a total of 14,000,000 gallons of water daily from the River Dove. The total value of the contract is £231,000.

Miscellanea

MR. J. E. MACKAY.—We record with regret the death of Mr. John Eric Mackay, which occurred on June 30th. He was the chief electrical designer of Mavor and Coulson, Ltd., with whom he had spent the whole of his professional career. Mr. Mackay began his apprenticeship with Mavor and Coulson, Ltd., in April, 1906.

B.I.S.R.A. OPEN DAYS.—The British Iron and Steel Research Association will hold open days at its Sheffield laboratories on Thursday and Friday, September 6th and 7th next. The principal object is to provide an opportunity for representatives of member-firms to see the progress of the divisions of B.I.S.R.A. which are housed in Sheffield; they are mechanical working, steelmaking, and metallurgy (general). But there will also be displays of the work that is being conducted in the other establishments of the Association in London, Swansea and Normanby.

FORGING MACHINE FEEDING DEVICE.—An automatic feeding device can now be fitted to the horizontal forging machines made by Eumuco (England), Ltd., 12, Great Portland Street, London, W.1. This device is synchronised with the forging mechanism. In it the stock to be forged is gripped by mechanical tongs, and the piece is transferred from one die station to the next between the working strokes by the combined action of a pull down rod and an extractor wedge. At the end of the forging cycle the work is released into a discharge chute and the tongs return to the starting point.

GOVERNMENT STOCKS OF COPPER.—The Board of Trade says that it is about to make arrangements for reducing its stocks of copper. This is in accordance with the announcement in the Defence White Paper that the United Kingdom's strategic holdings of industrial raw materials would be reduced during the present year. The Board proposes to release up to 36,000 tons of copper in the current financial year, and will discuss with trade representatives how disposals may best be arranged so as to avoid undue disturbance to the market. These consultations are expected to take at least a month, and no sales of copper will therefore be made before the middle of August.

JUBILEE NUMBER.—This month celebrates the fiftieth anniversary of the founding of *The Shipbuilder and Marine Engine-Builder* by the late Mr. A. G. Hood. This achievement of fifty years of continuous publication is marked by a special July issue of this technical journal, which deals with all aspects of shipbuilding and marine engineering at home and abroad. In addition to the normal contents describing new ships and developments of marine interest there are congratulatory messages from six eminent shipbuilders and shipowners and two articles contributed by Lloyd Woollard, M.A., who writes about the practical and technical progress in shipbuilding and marine engineering during the past half a century and reviews the changes in the design and construction of warships during the same period.

TRANSPORT COMMISSION'S TRAINING ESTABLISHMENTS.—The British Transport Commission has stated that it is in the process of purchasing New Lodge, Windsor, for use as a residential training establishment. The Commission has been giving consideration to its training arrangements in the light of the needs of the railway modernisation plan and the drive for increased productivity, and has already announced its intention to establish its own school for training in work study. So that work study training can start in the early autumn it has been decided to utilise an existing training establishment at Watford for this purpose. New Lodge will be used to meet the essential residential training requirements of British Road Services, British Transport Docks, British Transport Waterways and London Transport, as well as some of the requirements of British Railways. These undertakings have a staff of over 700,000, and, the Commission says, the provision of residential training facilities accords with the best modern practice of large-scale industry, whether publicly or privately owned.

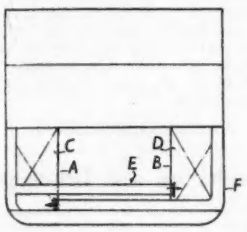
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. each.

MARINE ENGINEERING

750,660. April 9, 1954.—MEANS FOR STABILISING DAMAGED SHIPS, N. V. Koninklijke Maatschappij " de Schelde," Vlissingen, Zeeland, the Netherlands.

The object of the invention is to provide corrective stabilising means on damaged ships to come into operation automatically and immediately, independently of human agency. In the drawing it is assumed that the ship contains at least one set of two closed compartments, *A* and *B*, such as liquid tanks or cooling holds, at the sides of a ship, each of which is subdivided by a transverse partition, *C* and *D*, respectively. The dimensions of these compartments are such that dangerous listing can occur only when the sub-sections of one of the compartments are flooded simultaneously. According to the invention, in the construction illustrated in the drawing, substantially angle-shaped tubes, *E* and *F*, respectively, are fitted on either side of each transverse partition, *C* and *D*, the horizontal



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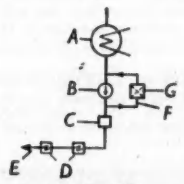
sections of the tubes extending transversely and being in communication with the respective sub-sections of the opposite compartments, *D* and *C*, respectively, while the vertical tube sections extend upwards along the relative sides of the ship and reach up to or nearly up to the lower deck. It will be apparent that if a collision occurs in a point near the transverse partition, *C* or *D*, of one of the compartments, the vertical sections of the respective tube will be destroyed, so that it is not only the two sub-sections of the compartment in question that will be flooded, owing to which the ship would list dangerously, but also via the horizontal tube sections, the sub-sections on the compartment on the opposite side of the ship, so that the dangerous list is corrected automatically and immediately. The outer walls of the vertical tube sections may be formed by the ship's skin, while an adjoining wall may be formed, if desired, by the transverse partition itself, in order to ensure the destruction of the tubes upon collision. Modified designs are also shown in the specification. —*June* 20, 1956.

STEAM POWER PLANTS

751,173. June 8, 1954.—REMOVAL OF SALTS FROM RETURN FLOW CONDENSATE, Sulzer Frères, Société Anonyme, Winterthur, Switzerland.

The invention relates to the removal of salts from the return flow condensate in steam power plants. It extends to steam plants themselves as well as to processes used in them. According to one aspect of the invention, a steam power plant includes a pipe for tapping off a portion of the return flow condensate,



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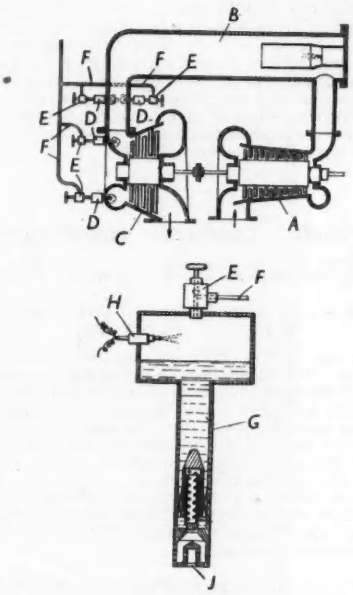
salts removal apparatus to which the tapped-off portion is supplied, and a pipe for returning the salt-free tapped-off portion from the salts removal apparatus to the condenser or to a point in the main stream of condensate before the tapping-off pipe. Three different arrangements of part of a steam plant through which the condensate flows, and the processes by which these arrangements are worked, are described in the specification. As shown in the drawing, the main stream of condensate is drawn from the condenser *A* by a pump *B* and flows through the cooler *C* of a stream jet air injector, arranged to provide the necessary vacuum in the condenser, after which it passes through pre-heaters *D* heated by tapped steam and then through a feed pipe *E* into the boiler (not shown). In the arrangement illustrated a portion of the condensate is tapped off between the condensate pump *B* and the cooler *C* of the air ejector through a pipe *F* and is introduced into a salts removal apparatus *G*, which removes salts from the condensate, for instance by ion exchange. After this treatment the now completely salt-free tapped-off portion is returned to the main stream before the condensate pump *B*. In this case the head produced by the condensate pump is used with advantage in circulating the tapped-off portion. There is a further advantage that tapping off a portion of the condensate in this way not only effectively reduces the salt content of the main stream of condensate but also ensures steady operation of the condensate pump. In a second arrangement the condensate tapped off to the salts removing apparatus is taken from the main condensate stream only after the cooler of the air ejector, while in a third arrangement the salt-free tapped-off portion of the condensate is returned directly into the condenser.—*June* 27, 1956.

GAS TURBINES

751,146. April 9, 1954.—REMOVING DEPOSITS FROM MACHINE ELEMENTS IN POWER PLANTS, Aktiengesellschaft Brown, Boveri and Co., Baden, Switzerland.

The invention provides a method of removing deposits from machine elements in thermal power plants. In the upper drawing *A* indicates a compressor, *B* a combustion chamber and *C* the gas turbine of a simple gas turbine plant. Pressure vessels with an ejector tube, valve and spray nozzle are indicated at *D*. The pressure vessel which may have any shape, is provided with an inlet valve *E* to which a pressure pipe *F* is connected. An injector tube *G*



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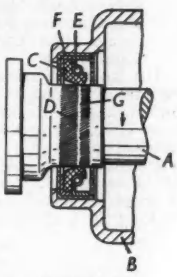
with a spring-loaded valve, at the end of which is a nozzle *J*, is also connected to the pressure vessel; *H* is an ignition device. If deposits of dust, soot or slag have to be removed from the blades of gas turbines which are in operation, at least one sudden temperature change is produced temporarily in the working medium which flows over the deposits that are to be removed so that they are loosened by thermal stresses without affecting the strength of the material forming the machine elements. This change in temperature is a decrease. In order to achieve the effect a measured quantity of liquid is injected into the stream of the working medium. The liquid (for example water) is either finely vaporised so that it immediately evaporates, or is injected in such a way that it only completely evaporates at the points where the deposits are, thus intensifying the cooling effect. The pressure vessels, as indicated in the upper drawing, may be located close to or some distance away from the deposit points, for instance either in the working medium supply pipe between combustion chamber *B* and turbine *C*, or in the inlet casing of the turbine directly in front of the blades. The measured amount of liquid is supplied to the pressure vessels by way of valves *E*, and the inside of the pressure vessels is put under pressure with the result that valves are made to open and the measured quantity of liquid in each vessel is injected through nozzles *J* into the working medium stream. The pressure vessels can also be equipped with the ignition device by means of which the required pressure for injecting the measured quantity of liquid is produced by the ignition of an explosive gas mixture in the pressure vessel itself.—*June* 27, 1956.

POWER TRANSMISSION

751,297. June 10, 1954.—ROTARY SHAFT-SEALING MEANS, Daimler-Benz Aktiengesellschaft, Stuttgart-Untertürkheim, Germany.

The invention relates to rotary shaft-sealing means comprising return rifling on the shaft. Referring to the drawing, the shaft *A* to be sealed is mounted in a housing *B* through which it passes. For preventing flow of oil along the shaft through the opening, there is fitted a sealing ring *C* of yieldable material, such as rubber, with a lip or sleeve part so that relative motion longitudinally of the shaft can take place between the shaft *A* and the ring. The lip of the ring encircles an end part of the shaft of enlarged diameter and this part is formed with grooves *D* which are helical or directed obliquely in relation to the longitudinal axis of the shaft. These grooves *D* constitute what is referred to as " the return rifling." The direction of the grooves is such that during rotation of the shaft they have a screwing effect which tends to reverse any outward flow of oil and return it inwards. This action assists the normal sealing action of the sealing ring. The grooves are numerous and very shallow. The lip of the ring is held tightly around and in contact with the grooved part of the shaft by an encircling spring ring *E* and the ring and spring are enclosed in an appropriate casing *F* which is removably inserted into a hollow boss on the housing as illustrated. Owing to the delicacy of the grooves, these become worn away during use, so that a smooth path *G* is produced around the shaft, but portions of the grooves at each side of the path remain to perform the oil return function.—*June* 27, 1956.

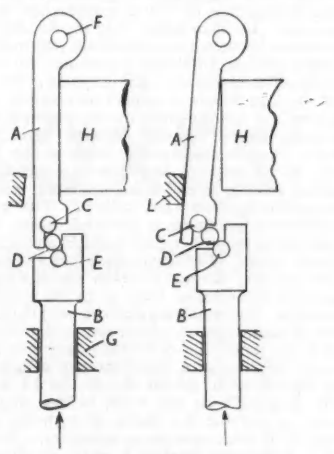


No. 751,297

ELECTRICAL ENGINEERING

744,474. November 14, 1952.—ELECTROMAGNETIC SWITCHES, The British Thomson-Houston Company, Ltd., Crown House, Aldwych, London, W.C.2. (*Inventors: Cyril Frederick Gimson and John Owen Tattersall.*)

The invention relates to toggle mechanisms used in electric switches. Referring to the drawing, it will be seen that the toggle mechanism comprises a pivotally mounted control member or armature *A*, an operating member or rod *B* and rollers *C*, *D*, and *E*, mounted between them. The armature is pivoted on a pin *F*, while the operating member *B* which may be connected to, or form part of a circuit breaker, can slide vertically in a guide *G*. It is biased upwards in the direction indicated by the arrows by springs (not shown). The electromagnet with which the armature *A* is associated is indicated at H. With the electromagnet energised and the armature attracted to it in the position shown in the left-hand



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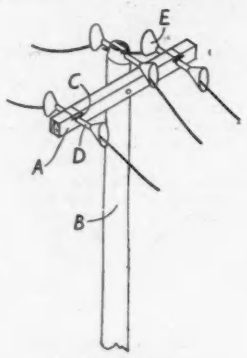
view, the axes of the rollers lie substantially in a single plane. They are restrained in this position by parallel abutments on the armature and contact operating rod, respectively. The rollers *C* and *E* are shown as mounted in recesses formed at the corners of the

shoulders so that, in the position indicated, the toggle is in compression. The axis of the roller *E* is located on the axis of the contact actuating member *B*, this axis, in the arrangement illustrated, passing through the axis of the pivot pin *F* on which the armature is rotatable. When the electromagnet is de-energised, the armature is released and forced out against a stop *K*, and the toggle moves to the position indicated in the right-hand view allowing the contact operating member to rise and open or close contacts associated with it. Re-energisation of the electromagnet restores the toggle to the position shown in the left-hand view. The toggle mechanism is suitable for use in connection with the circuit controller described in specification No. 742,114.—*February* 8, 1956.

751,124. March 2, 1954.—SUPPORTING AND INSULATING SYSTEMS FOR OVERHEAD ELECTRIC LINES, George Osborne McLean, "Four Winds," Station Road, Nailsea, Somersetshire (formerly of 8, Carnarvon Road, Bristol 6), and Archibald George Milne, Glen House, The Folly, Saltford, Somersetshire.

The invention relates to systems for insulating bare metal conductors carrying electric current at a high voltage. The invention is shown as applied to an 11,000V three-phase 50-cycle alternating current distribution system in the drawing. One support is a straight Baltic fir pole about 30ft long planted about 6ft in the ground. An oak or hard wood cross-arm *A* about 4in square and about 5ft in length is fixed to the pole *B* about 6in from the top. About 3in



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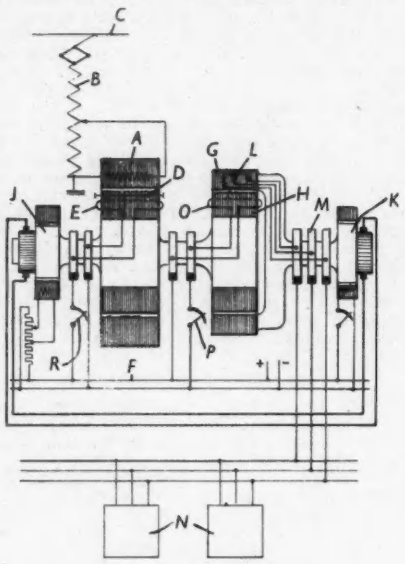
from each end of the cross-arm a groove *C* is cut shaped to suit the size of conductor and the securing wedge. In these grooves are placed tubes *D* of a material with a high dielectric strength such as porcelain. The tubes are of such a shape that they can be secured to the cross-arm by wooden dovetail wedges and they have skirts or bell shapes *F* at each end to attenuate the electric stress gradually and to give a large creepage distance between conductor and wood cross-arm.—*June* 27, 1956.

747,082. September 10, 1954.—ELECTRIC CONVERTERS FOR LOCOMOTIVES, Aktiengesellschaft Brown, Boveri and Co., Baden, Switzerland.

The invention relates to electric converters for locomotives with driving motors which are fed from a single-phase overhead line, particularly with commercial frequency, by way of a phase and frequency converter. Its main object is to provide for a clear separation between the single-phase and multi-phase systems without additional outlay and for the possibility of increasing the starting torque of the driving motors in as simple a manner as possible. In the drawing *A* is a single-phase motor, preferably a synchronous motor, supplied through transformer *B* from a 50-cycle single-phase overhead line *C*. The rotor of the single-phase motor is provided with a damper winding *D* and a d.c. excitation winding *E*, fed by sliprings from a d.c. system *F*. Furthermore a synchronous generator is provided which has two concentric rotating members *G* and *H*, an external and internal rotor. The single-phase motor *A* indirectly drives the internal rotor *H* and by way of a regulating gear also the external rotor *G* of the synchronous generator. The regulating gear can be in the form of a Ward-Leonard system comprising a d.c. dynamo *J* and a d.c. motor *K*. A hydraulic gear can however be used in place of a Ward-Leonard system. With the Ward-Leonard system the dynamo *J* is mechanically coupled with the rotor of the single-phase motor *A* and the d.c. motor *K* with the external rotor *G* of the synchronous generator. This rotor has a three-phase winding *L* which by sliprings *M* supplies the alternating voltage for driving motors *N* which are constructed with squirrel-cage rotors. The outer rotating part *G* of the synchronous generator can be rotated by the d.c. motor *K* in Ward-Leonard connection either in the same direction of rotation as that of the internal rotor *H*, or in the reverse direction, so that a variable frequency of 0–100 c/s can be taken from sliprings *M* for feeding the driving motors *N*. The adjustment of the driving motors, especially at low speeds and particularly during starting, is achieved by varying the excitation of d.c. excitation winding *O* of the synchronous



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generator by means of a regulating resistor *P*. The required relative increase in voltage at low frequencies can, for instance, be achieved automatically with the frequency regulation. The power factor of the locomotive is influenced by varying the d.c. excitation *E* of the single-phase motor by means of a regulating resistor *R*. A simplified constructional form where both the single-phase motor and the synchronous generator of the phase-and-frequency converter are combined on one machine is also shown in the specification.—*March* 28, 1956.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

TROLLEY AND CONTACT WIRE FOR ELECTRIC TRACTION

No. 23 : 1956. Price 4s.—In this revision of B.S. 23 : 1949 an additional standard size of contact wire (0·166 square inch section) has been introduced, primarily for use in high-voltage alternating current railway electrification. The requirements are substantially the same, for both copper and cadmium-copper wires, as in the previous edition, but a bending test is now specified in addition to the tensile, elongation and torsion tests. The electrical resistance is now related to the standard reference temperature of 20 deg. Cent. adopted generally in British Standards for electrical conductors.

DESIGN OF ELECTRICAL APPARATUS HAVING DOUBLE INSULATION

No. 2754 : 1956. Price 4s.—The normal method of protection against electric shock for all electrical appliances used in the United Kingdom is the connection of the frame or exposed metal parts of the appliance to earth. In recent years there has been a tendency for an alternative method known as "double insulation" to be used. This method is particularly useful where a satisfactory connection to earth cannot be arranged, and it appears probable that the use of double-insulated appliances will increase.

The purpose of the memorandum 2754 : 1956 issued by the British Standard Institution is to explain the principles involved in the design of electrical apparatus having double insulaton, and it is intended primarily for the use and guidance of B.S.I. Committees. It is, however, likely to be of interest to all designers, manufacturers and users of electrical appliances. The report first gives general notes on protection against electric shock and then deals with the design of double-insulated appliances and the various forms in which double insulation can be used. The various kinds of design are illustrated diagrammatically. The use of double insulation as a protection against electric shock instead of the method of earthing which is normally required has been recognised by the Regulations for the Electric Equipment of Buildings issued by the Institution of Electrical Engineers, provided that the double-insulated appliance is the subject of an appropriate British Standard which has been approved for the purpose of the Regulations. For the guidance of B.S.I. Committees who may be called upon to draft such British Standards for particular appliances, a section on the testing of double insulation has been included in the memorandum.

COPPER AND CADMIUM-COPPER STRANDED CONDUCTORS FOR OVERHEAD ELECTRIC TRACTION SYSTEMS

No. 2755 : 1956. Price 5s.—This new publication provides a range of standard stranded conductors suitable for overhead electric traction systems. Contact wires have been standardised for many years in B.S. 23, but with the extensive electrification of railways a need has arisen for standard stranded conductors for such purposes as catenaries and feeders. Apart from the wider range of sizes and different lay ratios, the requirements of the new standard are similar to those of B.S. 125 and B.S. 672, which deal with copper and cadmium-copper conductors for power transmission systems.

METHODS OF TESTING VULCANISED RUBBER

No. 903, Part C3 : 1956. Price 2s. 6d.—Since the recent issue of a number of revised parts of B.S. 903, "Methods of Testing Vulcanised Rubber," the British Standards Institution has now published Part C3, "Permittivity and Power Factor of Insulating Soft Vulcanised Rubber and Ebonite," which is the first revised part relating to electrical tests. The document does not differ greatly from the 1950 version, except in the layout and in the adoption of metric dimensions.

Catalogues and Brochures

A. A. JONES AND SHIPMAN, Ltd., Narborough Road South, Leicester.—Leaflet describing model 1730 and model 1731 precision dividing tables.

AIMS OF INDUSTRY, Ltd., 12, Carteret Street, London, S.W.1.—Booklet entitled "Physiotherapy in Industry," giving details of treatments carried out and the results obtained by organisations having their own physiotherapy department.

EDWARDS HIGH VACUUM, Ltd., Manor Royal, Crawley, Sussex.—Illustrated folder No. E. 177/2, describing a ½ lb capacity vacuum furnace suitable for sintering, melting and casting up to a temperature of 1700 deg. Cent., with 1800 deg. Cent. possible for short periods.

IGRANIC ELECTRIC COMPANY, Ltd., Bedford.—Booklet describing "Igranic-Stromag" electromagnetic multi-disc clutches. All sizes in the range described are available either as dry plate or as lubricated plate clutches. Line drawings illustrate the construction of these clutches.

EFCO-EDWARDS VACUUM METALLURGY, Ltd., Manor Royal, Crawley, Sussex.—Illustrated folder No. E180/2, dealing with medium-size high-vacuum melting and pouring induction furnaces, capacities 28 lb (12·7 kg) and 56 lb (25·4 kg). A block plan of a typical layout is included, together with a list of the water and power supplies required.

GENERAL ELECTRIC COMPANY, Ltd., Magnet House, Kingsway, London, W.C.2.—Booklet outlining the development of an atomic energy department created by The General Electric Company, Ltd., and Simon-Carves, Ltd., for the designing, developing and building of atomic power stations. The atomic energy group is now established at Fraser and Chalmers Engineering Works, Erith, and is able to draw on the resources of both the G.E.C. and Simon-Carves organisations.

JOHNSON, MATTHEY AND CO., Ltd., Hatton Garden, London, E.C.1.—Illustrated brochure entitled "An Industry Within Industry," describing some of the products and services of the company. The opening paragraph states that: "The primary function of Johnson Matthey is to refine the precious metals—silver, gold and the metals of the platinum group—and to process them and also certain base metals into the materials and components needed by commerce and industry."

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

INSTITUTION OF ELECTRICAL ENGINEERS

Sat., July 28th.—LONDON GRADUATE AND STUDENT SECTION: Summer Outing, 1956. Visit to the College of Aeronautics, Cranfield, combined with a visit to Woburn Abbey, 8.30 a.m. (Savoy Place, W.C.2.)

INSTITUTION OF NAVAL ARCHITECTS

Thurs., Oct. 11th.—Weir Lecture Hall, 10, Upper Belgrave Street, London, S.W.1, "Scale Effect Experiments on Victory Ships and Models," Part II, "Analysis of Wake Measurements on a Model Family and the Model Boat," D. C. Endert, Jr., J. D. van Manen, 4.45 p.m.

ROYAL METEOROLOGICAL SOCIETY

Thurs., to Sat. July 26th to 28th.—Pantycelyn Hall of Residence of the University College of Wales, Aberystwyth, two-day meeting in honour of Sir David Brunt.

WEST OF SCOTLAND IRON AND STEEL INSTITUTE

Fri., Oct. 19th.—39, Elmbank Crescent, Glasgow. Symposium on the application of Low-Alloy Steels for Welded Pressure Vessels, 10 a.m.